# VEGETATION-SOIL UNITS in the central Oregon juniper zone

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# Introduction

Efficient and successful land management is more likely when the landscape is classified into natural ecological units of effective environment. Such a system of classification must include several characteristics specific to each unit so that the units may be readily recognized and identified even though some characteristics may be altered or destroyed. Since plant communities and the soils supporting them are functional products of the same longtime environmental interactions, characteristics associated with the two complexes and an understanding of their relationships provide the basis for the needed classification.

A classification designed in this manner is not available for the central Oregon juniper zone, even though the area has long been used for grazing and agricultural crop production. In fact, few scientific investigations have been made to provide any knowledge of the ecology of the area. Jensen (1945)[1] developed empirical standards to classify range conditions in the "grassland-juniper" type in central Oregon, but he supplied little quantitative data concerning characteristics of the virgin area and did not attempt to classify particular plant communities.

[1] Names and dates in parentheses refer to Literature Cited, p. 46.

Eckert[2] classified vegetation-soil units in some *Artemisia*[3] types in northern Harney County in eastern Oregon. *Juniperus occidentalis* occurs in some of these communities, but these units are not distinctive of the juniper zone. Numerous other studies describing plant communities where juniper species occur in the Western United States have been made (Cottle 1931, Emerson 1932, Merkle 1952, Rasmussen 1941, Woodbury 1947, Woodin and Lindsey 1954). However, the results of these have little direct bearing on the ecology of the central Oregon juniper zone.

This work defines and characterizes some vegetation-soil units represented by relatively undisturbed areas. The units were interpreted on the basis of holistic and polyclimax concepts of ecology (Billings 1952, Daubenmire 1952, Tansley 1935). Vegetation, soil, and topographic relationships having a bearing on identification and classification of disturbed places in the study area are discussed as well as some thoughts on how the results may be used in a practical manner.

[2] Eckert, Richard Edgar, Jr. Vegetation-soil relationships in some *Artemisia* types in northern Harney and Lake Counties, Oregon. 208 pp. 1957. Ph.D. thesis on file Oregon State University.

[3] A list of common and scientific plant names is in Appendix 1.

# The Area

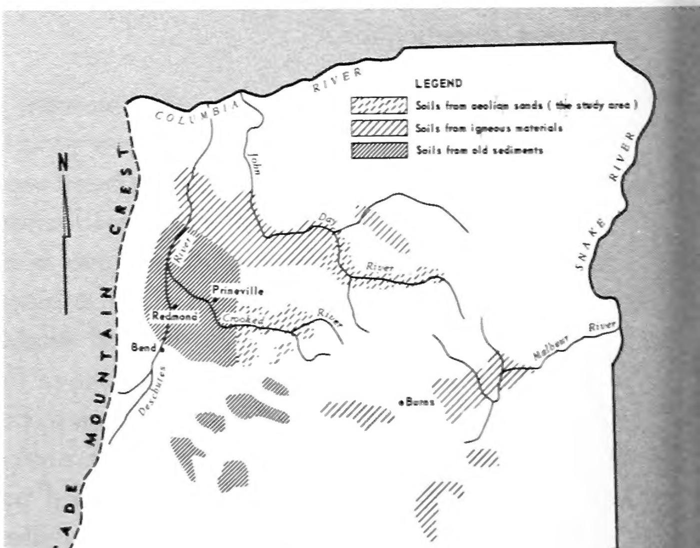
## Physiography

The central Oregon juniper zone includes approximately 108,000 acres in Crook, Deschutes, and Jefferson Counties where western juniper is a major component of the vegetation. This area is one of three physiographic subdivisions of the Northwest representative of the pinyon-juniper zone in the Western United States. Although no pinyon pines occur in the Oregon area, other features are similar to the broad parent zone. Soils are generally shallow and stony. The climate is characterized by high summer temperatures, cool winters, high winds, low relative humidity, and low annual precipitation. In the study area, the zone grades to the ponderosa pine zone, where moisture is more effective, and to the sagebrush or grassland zones of less effective moisture.

The three physiographic subdivisions are based on soil parent materials (fig. 1). In the study area, soils are derived from wind-laid and mixed igneous and pumice sands or, where these materials do not comprise the actual parent material, pumice is scattered throughout the soil profile. Where pumice is present, but not as a major soil forming material, it is found mostly in the A horizon. The pumice probably originated from Mount Mazama (site of Crater Lake), 100 miles southwest of Bend, when the volcano exploded approximately 8,000 years ago (Williams 1942). Some pumice may have originated from more recent eruptions of Newberry Crater (site of Paulina and East Lakes), located 25 miles south of Bend. The igneous sands, mostly from andesite, rhyolite, or basalt, were transported from dry lakebeds by southwesterly winds.

A second physiographic subdivision of the Oregon juniper zone has soils derived mostly

Figure 1.—Distribution of the physiographic subdivisions of the juniper zone in eastern Oregon.



## CORRECTION

Driscoll, Richard S. Vegetation-soil units in the central Oregon juniper zone. U.S. Forest Serv. Res. Paper PNW-19.

In figure 1 on page 2, the top and bottom symbols of the legend should be reversed.

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of igneous materials. This soil forming substance is varied, comprised of rhyolitic, andesitic, or basaltic lava flows which occurred over long periods of geologic time. Some of the oldest flows originated during the Miocene epoch (Hodge 1942). Others occurred intermittently up to Recent time.

The third physiographic subdivision has soils derived primarily from sedimentary materials and is located principally in the upper regions of the John Day and Crooked Rivers. These sediments, primarily the Clarno and John Day formations, were water deposited during the Eocene and Oligocene epochs (Kellogg 1927).

## Climate

The regional climate of the study area is continental, modified by marine air currents from the Pacific Ocean. It is semiarid, characterized by low annual precipitation, dry summers with warm days and cool nights, and cool-to-cold, relatively snow-free winters. No month is frost free, although killing frosts generally do not occur during June, July, and August.

Annual precipitation varies greatly by locality and year. At Bend, located in the transition between the juniper and ponderosa pine zones, the average annual precipitation, based on 56 years of record, is 12.25 inches (U. S. Weather Bureau 1959). The highest recorded was 25.95 inches in 1907 and the lowest recorded was 5.75 inches in 1959. At Redmond, 20 miles north of Bend and in the center of the area, the average annual precipitation, based on 29 years of record, is 8.54 inches with a high of 14.19 inches in 1948 and a low of 4.39 inches in 1949. Approximately 88 percent of the annual precipitation occurs as rain and snow fairly evenly distributed from October through June. The summer months are droughty, frequently completely dry. Precipitation that does occur during the summer is ineffective for perennial plant growth because of low-intensity storms (usually less than 0.25 inch per storm) and high day temperatures (usually exceeding 80° F).

When the study was made, 1959 and 1960, the area suffered one of the severest droughts on record. Table 1 summarizes precipitation data for these 2 years, computed on an October-June forage-year basis to show departures, totals, and long-term means at Bend and Redmond. This untimely climatic sequence undoubtedly influenced plant growth, particularly herbaceous species, resulting in a climatic bias of the vegetation data.

## Topography and Geology

The elevational range of the study area varies from 2,200 to 5,000 feet above sea level. The western part of the area is characterized by a

Table 1.—Departures, totals, and long-term means for 1958-59 and 1959-60 forage-year precipitation at Bend and Redmond, Oreg.[1]

| Station and year | Month: Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Forage-year total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inches | | | | | | | | | |
| Bend: | | | | | | | | | | |
| 1958-59 | -0.61 | -0.75 | -1.18 | -0.59 | 0.41 | -0.03 | -0.61 | -0.39 | -0.95 | -4.70 |
| 1959-60 | - .49 | -1.19 | -1.15 | - .58 | .40 | 1.52 | .22 | - .54 | -1.24 | -3.89 |
| Mean | .93 | 1.45 | 1.83 | 1.85 | 1.03 | .76 | .68 | 1.12 | 1.25 | 10.90 |
| Redmond: | | | | | | | | | | |
| 1958-59 | - .67 | .56 | .13 | - .02 | .30 | - .56 | - .58 | - .47 | - .43 | -1.74 |
| 1959-60 | - .11 | - .60 | - .92 | .89 | .45 | 1.38 | - .11 | - .24 | -1.08 | - .34 |
| Mean | .69 | .90 | 1.11 | 1.04 | .70 | .56 | .58 | .82 | 1.08 | 7.48 |

[1] No sign or minus (-) sign indicates positive or negative departures from means.

nearly level to rolling upland plain dissected by deep V-shaped gorges of the Deschutes and Crooked Rivers. The eastern part is characterized by numerous buttes rising from 500 to 1,500 feet above the floor of the plain.

The plain area is highly variable. South of the Crooked River, it is interlaced by ropey, basaltic lava flows of Recent time. Deep sands of mixed pumice, andesite, rhyolite, and basalt occur between the lava flows. North of the Crooked River, occasional diastrophic buttes composed of John Day and Clarno sediments have been uplifted 500 to 1,500 feet above the plain floor. Among these buttes, highly variable alluvial material of the Madras and Cascan formations occurs. A relatively large quantity of pumice is mixed with this material. Occasional pumice "pockets" of varying area and depth occur throughout the plain area.

Some of the buttes in the eastern part of the study area have lava flows dating from Recent time, but most buttes appear to have been formed by diastrophism. Occasional "cinder cones," low cone-shaped buttes with extensive volcanic cinder deposits on their slopes, occur in the central part of the area near Redmond. The diastrophic buttes are heterogeneous. Most of them are capped with rhyolitic and/or andesitic lavas. Tuffaceous sediments appear beneath the lava flows. Sand deposits of similar appearance to those found among the lower lying lava flows occur on the lee side of the buttes and ridges.

## Soils

The soils in the area are in the Sierozem, Brown, and Chestnut great soil groups (Knox 1957). Brown soils and their associated Azonal Regosols are most common. The Chestnuts are minor in extent, occurring mostly on north and northeast slopes where temperature and precipitation have favored their development. Sierozems are also limited, occurring in the hotter, drier portions of the area.

The soils are mostly light colored, with gray to light-yellowish-brown A horizons and accumulations of soluble salts or siliceous materials on individual soil peds or rocks in the profile. They are low in organic matter and have low carbon-nitrogen ratios.

Most of the soils are sandy loams, but textures range from loamy coarse sand to clay loam. Structure in the B horizon ranges from strongly developed prismatic to weak subangular blocky. Many of the soils lack B horizons. In most cases, large volumes of the solum are occupied by stones.

The depth of the solum ranges from 14 to 44 inches but is generally around 30 inches. The underlying materials affecting plant growth include solid or cracked bedrock, hardpans which are often discontinuous, or semiconsolidated mixtures. The cracked bedrock usually has thin films of soil in the cracks, allowing deeper root penetration than might be expected. Some of the "apparent" bedrock becomes loose and friable when moist, providing an acceptable medium for root growth.

Vesicular plates are common on the surface of most of the undisturbed soils. The role of these 1- to 2-inch-thick plates in plant growth and distribution is not well understood.

The soil surface is slightly acid (pH 6.0) to neutral (pH 7.0). Soil reaction increases with depth, becoming slightly alkaline (pH 7.5) to alkaline (pH 8.0) at the bottom of the B horizon. White calcareous or siliceous deposits on individual soil peds or on the undersides of rocks are common in the subsoil.

Although a soil survey has been conducted on lands used for farming within the study area (Leighty 1958), none of the classified units was observed during this study.

## Vegetation

*Juniperus occidentalis* is the dominant tree species of the area. An occasional *Pinus ponderosa* may be found in canyon bottoms or on north slopes where soil moisture is more effective. Natural wide spacing of individual junipers provides the aspect of a savanna (fig. 2). *Artemisia tridentata* is most often the dominant shrub in the understory. Occasionally it is displaced wholly or to codominance by *Purshia tridentata*. Other shrubs characteristic of the area are *Chrysothamnus nauseosus, C. viscidiflorus, Tetradymia canescens, Leptodactylon pungens,* and *Artemisia arbuscula*. *Ribes cereum, Grossularia velutina,* and *Grayia spinosa* occur infrequently. Suffrutescents are represented by various species of *Eriogonum*.

*Agropyron spicatum* and *Festuca idahoensis* are the characteristic grasses of relatively undisturbed communities. *Poa secunda* and *Stipa thurberiana* are common. Other grasses include *Sitanion hystrix, Stipa comata, Bromus tectorum, Festuca octoflora,* and *Koeleria cristata*.

Forbs commonly do not constitute major components of relatively undisturbed communities. Some of the more common perennial forbs are *Agoseris* sp., *Achillea millefolium, Eriophyllum lanatum, Astragalus* spp., *Erigeron linearis,* and *Lupinus* spp.

Figure 2.—Wide spacing of individual trees provides the characteristic savanna aspect of the central Oregon juniper zone.

# Methods

Prior to making detailed measurements, plant associations[4] were classified on a tentative basis by reconnaissance. Insofar as possible, these units represented areas relatively undisturbed by grazing or other land uses. This initial separation was based primarily on the vegetational physiognomy of the units. Also considered were soil characteristics including amount of bare soil surface, soil stoniness, solum depth, and nature of the underlying material. Although subjectivity in this initial classification is implied, it is tolerable. Greig-Smith (1957) emphasizes that areas subjectively selected as being distinctive and not transitional on the basis of predefined criteria are evidence they represent specific entities.

For each association recognized from the initial reconnaissance, five 50- by 100-foot macroplots were located in representative stands with care taken to avoid ecotones. Within each macroplot, four 50-foot combination line-belt transects were located in restricted random fashion. Along each transect, ten 1- by 2-foot observation plots were systematically placed. This sampling scheme has been discussed by Poulton and Tisdale (1961).

[4] An association is ". . . the fundamental unit of phytosociology, being a plant community of certain floristic composition, of uniform habitat conditions and of uniform physiognomy" (Wildeman 1910). The term as used here is applied only to climax communities defined according to polyclimax concepts.

Measurements of vegetation included: (1) percent foliage cover of individual species, (2) percent basal area of perennial herbs, (3) average maximum heights of mature, shrubby, and suffrutescent species, and (4) density counts of shrubby and suffrutescent species. Related data were obtained on the percentage of the soil surface not occupied by living or dead plant material.

Percent foliage cover of all herbaceous species, basal area of perennial herbaceous species, and bare soil surface were ocularly estimated on the small observation plots. Foliage cover of shrubs was measured by the line intercept method (Canfield 1941) on the 50-foot line transects. Shrub density was obtained by counting all individuals rooted in a 4-foot belt transect bisected by each line transect. Average maximum heights of mature shrubs were determined by measuring all mature plants within the belt transect. Percent foliage cover of trees was estimated over the whole of each association from aerial photographs (Moessner 1960). In addition, percent constancy of all species was computed on the basis of presence or absence within the bounds of the macroplots.

Soil data were obtained from pits dug immediately adjacent to each macroplot. Profile characteristics were described in accordance with procedures outlined in the Soil Survey Man-

ual (U. S. Bur. Plant Indus., etc. 1951) and tentative taxonomic soil units were established[5]. In addition, samples of the A horizon and the finest textured part of the B horizon, or the AC horizon of the Regosols, were collected and analyzed for (1) textural classes, (2) moisture equivalent, (3) 15-atmospheres tension, (4) bulk density, and (5) soil reaction (pH). In addition, percentages of organic matter and total nitrogen were determined for the A horizon.

The results of analyses for moisture equivalent, 15-atmospheres tension, and bulk density were used to compute the total available water storage capacity in the 2- to 14-inch soil zone (Broadfoot and Burke 1958). All soil analyses were made by the Soil Testing Laboratory of the Oregon Agricultural Experiment Station at Corvallis.

Slope aspect was determined by a compass and recorded as one of the eight points, i.e., northeast, south, southwest, etc. Elevation at each macroplot was measured with an aneroid barometer. Slope position is the place on slopes where macroplots were located and was estimated as to the upper, middle, or lower one-third.

No attempt was made to determine the areal extent of the classified units or to determine the sequence pattern of secondary succession.

[5] Descriptions of these units are presented in Appendix 2. Descriptions and unit interpretations were reviewed by Drs. C. T. Youngberg and E. G. Knox, soil specialists, Oregon State University.

# Results

## Classification of the Units

Relatively undisturbed plant communities show the integrated results of longtime environmental interactions. The floristics of the communities, particularly the dominants in the different community layers and the character and sociability of species, provide clues to the classification of homogeneous ecological entities. Associated abiotic factors, considered as independent and interacting influences on the communities, provide additional evidence for separating the units. On this basis, each plant association subsequently classified and described, together with its related soils and topographic characteristics, represents a component part of an individual ecosystem.

This investigation provided a classification scheme in which the vegetational and soil components of nine ecosytems and variants of two were named and characterized on the premise that they exist as demonstrable entities with both independent and intergrading characteristics. The variants are subunits very closely related to one of the classified entities but differ strongly from the entities in at least one differentiating characteristic. However, other evidence obtained did not seem to warrant classification of these subunits as separate systems. In all cases, primary vegetational and soil features selected for classification and characterization purposes were those which had become adapted to and expressed most fully the time and space relationships of the whole environment of the particular system. In some cases, constancy data were used to support unit separations based on the measured characteristics.

The generalized characteristics of the vegetation-soil units are shown in table 2. The entities are arranged in descending order of effective moisture interpreted on the basis of combined vegetative, soil, and topographic characteristics. The units were named according to the generic names of the most abundant plants in the tree, shrub, and herbaceous layers of each association. Generally, trinomial nomenclature was found adequate to briefly convey the vegetational physiognomy of the units. In some units, however, character species were the same but differed in dominance. This occurred between the *Juniperus/Artemisia/Festuca* and *Juniperus/Artemisia/Festuca-Lupinus* associations. In this case, the generic name of a forb showing 100-percent constancy in one association and considerably less in the other was used to differentiate the two units in name. Occasionally, one plant layer contributed little to the physiognomy of the community and binomial nomenclature was adequate. This occurred in the *Juniperus/Festuca* and *Juniperus/Agropyron* associations. Sometimes, two species of similar life-form were nearly equal in

Table 2.—Number of macroplots and generalized characteristics of vegetation-soil units in the central Oregon juniper zone

| Unit | Sample units | Aspect | Associated great soil group | Elevational range |
|---|---|---|---|---|
| | | Number | | Feet |
| *Juniperus/Artemisia/Festuca* | 5 | NW. to NE. | Chestnut | 4,250-4,500 |
| *Juniperus/Artemisia/Festuca-Lupinus* | 4 | N. to NE. | Regosol in Brown zone | 4,400-4,550 |
| *Juniperus/Festuca* | 5 | NW. | Brown | 4,100-4,300 |
| (*Purshia* variant) | (2) | (SE. to E.) | | |
| *Juniperus/Artemisia/Agropyron-Chaenactis* | 5 | NW. to NE. | Regosol in Brown zone | 3,900-4,400 |
| *Juniperus/Artemisia/Agropyron* | 5 | Level | Brown | 2,550-2,650 |
| *Juniperus/Agropyron* | 6 | E. to NE. | Brown | 4,150-4,450 |
| (*Purshia* variant) | (2) | (SE.) | | |
| *Juniperus/Artemisia-Purshia* | 5 | N. to NE. | Regosol in Brown zone | 4,100-4,400 |
| *Juniperus/Agropyron-Festuca* | 5 | E. | Regosol in Brown zone | 4,250-4,750 |
| *Juniperus/Artemisia/Agropyron-Astragalus* | 6 | S. to SW. | Brown | 4,000-4,400 |

abundance in certain plant layers. In such a case, the generic names of both species were used to name the associations. The *Juniperus/Artemisia-Purshia* and *Juniperus / Agropyron-Festuca* associations are examples.

Samples of at least five stands were used to classify and characterize all but one of the associations and the two association variants. One unit of the *Juniperus/Artemisia/Festuca-Lupinus* association was sufficiently different in floristic and soil characteristics that it was discarded from the analysis. Only two sample units were used to characterize the *Purshia* variants of the *Juniperus/Festuca* and *Juniperus/Agropyron* ecosystems. These variants were minor in areal extent. The main characteristics were the same as their respective associations, and sufficient representative stands could not be located for analysis.

Direction of slope appeared limiting in the occurrence of *Purshia* and the relative dominance of *Festuca* and *Agropyron*. *Purshia* was most common on southeast- to east-facing slopes. The associations with *Festuca* as the most abundant herbaceous species favored northerly slopes. Where *Agropyron* was most abundant in the herbaceous layer, the respective associations had southerly to level aspects. Exceptions occurred with the *Juniperus /Artemisia/Agropyron-Chaenactis* and *Juniperus /Agropyron-Festuca* associations where *Agropyron* was dominant in the herbaceous layers. These units occurred on northerly to east slopes with Regosolic soils whose characteristics apparently compensated other factors to favor stronger expression of *Agropyron*.

Relationships between associations and great soil groups were meager. In one case, however, two associations identical in general physiognomy were separated on the basis of related great soil groups. The *Juniperus /Artemisia/Festuca* associations occurred with a Chestnut soil. The *Juniperus/Artemisia/Festuca-Lupinus* association occurred with a Regosol. Elevation appeared nondeterminant in ecosystem distribution in the central Oregon juniper zone.

The diagnostic features of the units were organized into a taxonomic key of the associations based on vegetational, soil, and topographic characteristics easily recognized in the field. The key provides a way to identify each unit without detailed knowledge of the entities. It will assist the reader and potential user of the results of this study to remember some basic characteristics of the recognized vegetation-soil units. Immediately following the key are detailed descriptions of associations and their related soils.

## Key to the Associations

1. Associations occurring with zonal soils
   2. Associations occurring on northerly slopes with Chestnut soils of rhyolitic-andesitic colluvial origin; *Juniperus occidentalis, Artemisia tridentata,* and *Festuca idahoensis* comprising respectively 12-, 7-, and 11-percent cover --------- ***Juniperus/Artemisia/Festuca*** association
   2. Associations occurring on varied slopes with Brown soils of varied origin
      3. *Festuca idahoensis* dominant in the herbaceous layer (approximately 11-percent cover); *Juniperus occidentalis* comprising 77-percent cover; association normally occurring on the lower portion of north slopes on soils derived from volcanic tuff indurate when dry but friable and porous when wet ----------- ***Juniperus/Festuca*** association

         *Purshia* variant: Occurs on east to southeast slopes; *Purshia tridentata* comprises 4-percent cover; *Festuca idahoensis* comprises 5-percent cover
      3. *Festuca idahoensis* not dominant in the herbaceous layer and may be absent; *Agropyron spicatum* dominant in the herbaceous layer
         4. *Artemisia tridentata* in very small quantities (0.9-percent cover); *Juniperus occidentalis* and *Agropyron spicatum* comprising respectively 43- and 5-percent cover; association normally occurring on east to northeast slopes with soils of rhyolitic-andesitic colluvial origin --- ***Juniperus/Agropyron*** association

            *Purshia* variant: Occurs on southeast slopes; *Purshia tridentata* comprises 7-percent cover
         4. *Artemisia tridentata* in larger quantities (more than 7-percent cover)
            5. *Festuca idahoensis* absent in measured stands (present only under trees); *Juniperus occidentalis, Artemisia tridentata,* and *Agropyron spicatum* comprising respectively 28-, 7-, and 7-percent cover; *Astragalus lectulus* present in all stands; association occurring on south- and southwest-facing slopes with soils of rhyolitic-andesitic colluvial origin --***Juniperus/Artemisia/Agropyron-Astragalus*** associations
            5. *Festuca idahoensis* present in very small quantities (0.4-percent cover); *Juniperus occidentalis, Artemisia tridentata*, and *Agropyron spicatum* comprising respectively 10-, 8-, and 9-percent cover; *Astragalus lectulus* absent in all stands; association occurring on gently undulating uplands with strongly developed, almost rock-free soils of water- and/or wind-laid sediments ----- ***Juniperus/Artemisia/Agropyron*** association

1. Associations occurring with azonal Regosolic Brown soils of mixed aeolian igneous and pumice sands and found on the upper half of north to northeast slopes
   6. Associations occurring with soils developed from deep (45 inches) sands; *Artemisia tridentata* and *Purshia tridentata* sharing dominance (8- and 6-percent cover, respectively) in the shrub layer ------- ***Juniperus/Artemisia-Purshia*** association
   6. Associations occurring with soils developed from shallow (16 inches) to moderately deep (25 inches) sands, indurated hardpans present or absent

7. Associations occurring with soils developed from shallow (16 inches) sands; indurated hardpans present; *Agropyron spicatum* and *Festuca idahoensis* sharing dominance (3- and 2-percent cover, respectively) in the herbaceous layer; *Juniperus occidentalis* comprising 32-percent cover ____________ ***Juniperus/Agropyron-Festuca*** association

7. Associations occurring with soils developed from moderately deep (25 inches) sands; *Agropyron spicatum* or *Festuca idahoensis* dominating the herbaceous layer; indurated hardpans absent

   8. *Agropyron spicatum* dominant (4-percent cover) in the herbaceous layer; *Juniperus occidentalis* and *Artemisia tridentata* comprising 46- and 4-percent cover, respectively; *Chaenactis douglasii* present in all stands; *Lupinus* sp. absent in all stands ________ ***Juniperus/Artemisia/Agropyron- Chaenactis*** association

   8. *Festuca idahoensis* dominant (10-percent cover) in the herbaceous layer; *Juniperus occidentalis* and *Artemisia tridentata* comprising respectively 12- and 5-percent cover; *Chaenactis douglasii* absent in all stands; *Lupinus* sp. present in all stands __ ***Juniperus /Artemisia/ Festuca-Lupinus*** association

## Description of the Units

Summaries of specific vegetation and soil characteristics of the classified units are presented in tables 3, 4, and 5. Table 4 is a listing of the percent foliage cover and constancy of species arranged in relative order of dominance and constancy. Table 3 summarizes selected characteristics of the soils occurring with each association. Table 5 provides a comparison among the associations of the density and height measurements of shrubby and suffrutescent species.

Table 3.—Average values of selected surface and subsoil characteristics attendant to nine associations in the central Oregon juniper zone

| Association | Basal area perennial herbs | Bare soil surface | Available SMS[1] capacity, 2- to 14-inch zone | Organic matter, A horizon | Total nitrogen, A horizon | Horizon texture[2] | |
|---|---|---|---|---|---|---|---|
| | | | | | | A | B or AC |
| | Percent | Percent | Inches water | Percent | Percent | | |
| *Juniperus/Artemisia/Festuca-Lupinus* | 7.4 | 22.1 | 1.41 | 4.78 | 0.21 | l | c |
| *Juniperus/Artemisia/Festuca-Lupinus* | 6.5 | 30.9 | 1.98 | 1.74 | .10 | sl | sl |
| *Juniperus/Festuca* (*Purshia* variant) | 4.4 | 33.3 (46.8) | 1.81 (2.14) | 3.91 (2.33) | .17 (.10) | l (l) | sil, c (c) |
| *Juniperus/Artemisia/Agropyron-Chaenactis* | 5.2 | 52.3 | .87 | 1.59 | .08 | sl | sl |
| *Juniperus/Artemisia/Agropyron* | 6.6 | 41.3 | 2.31 | 1.50 | .08 | l | c, cl |
| *Juniperus/Agropyron* (*Purshia* variant) | 3.2 | 51.1 | 1.34 | 2.12 | .10 | scl (l) | c, cl |
| *Juniperus/Artemisia-Purshia* | 3.1 | 55.0 | 1.54 | 1.05 | .06 | sl | sl |
| *Juniperus/Agropyron-Festuca* | 4.1 | 54.7 | .97 | 1.32 | .07 | sl | sl |
| *Juniperus/Artemisia/Agropyron-Astragalus* | 3.5 | 45.7 | 1.21 | 1.63 | .08 | l | c |

[1] SMS, soil moisture storage.

[2] The AC horizon is immediately below the A horizon in Regosols. B horizon textures were taken for the finest part of that horizon. Textural classes: cl, clay loam; l, loam; scl, sandy clay loam; sil, silt loam; c, clay; and sl, sandy loam.

Table 4.—Mean foliage cover and constancy of species in nine classified associations of the central Oregon juniper zone[1] (In percent)

| Species | Association: *Juniperus/ Artemisia/ Festuca* | | *Juniperus/ Artemisia/ Festuca-Lupinus* | | *Juniperus/ Festuca* | | *Juniperus/ Artemisia/ Agropyron-Chaenactis* | |
|---|---|---|---|---|---|---|---|---|
| | Cover | Constancy | Cover | Constancy | Cover | Constancy | Cover | Constancy |
| *Juniperus occidentalis* | 12.0 | 100 | 12.3 | 100 | 76.7 | 100 | 46.0 | 100 |
| *Artemisia tridentata* | 7.4 | 100 | 5.1 | 100 | .9 | 100 | 4.1 | 100 |
| *Festuca idahoensis* | 10.8 | 100 | 10.4 | 100 | 10.8 | 100 | 1.9 | 100 |
| | | | | | (5.3) | (100) | | |
| *Agropyron spicatum* | 5.3 | 100 | 1.5 | 100 | 1.6 | 100 | 3.7 | 100 |
| *Poa secunda* | 1.6 | 100 | 1.0 | 100 | .9 | 100 | .7 | 100 |
| *Koeleria cristata* | .2 | 100 | .8 | 100 | .3 | 100 | .7 | 100 |
| *Astragalus* sp. | 1.4 | 100 | | | .1 | 60 | | |
| *Agoseris* sp. | .4 | 100 | | 25 | .1 | 40 | | |
| *Achillea millefolium* | .3 | 100 | | | .1 | 60 | .1 | 100 |
| *Lomatium triternatum* | .1 | 100 | .1 | 100 | | 100 | | |
| *Collinsia parviflora** | .6 | 100 | .1 | 100 | .2 | 100 | .6 | 100 |
| *Gayophytum lasiospermum** | .3 | 100 | | 25 | | 80 | .5 | 80 |
| *Lupinus* sp. | | 40 | 2.3 | 100 | .1 | 60 | | |
| *Phlox douglasii* | .3 | 40 | .3 | 100 | .2 | 100 | | |
| *Erigeron filifolius* | | | .3 | 100 | | | | |
| *Eriogonum microthecum* | | | .3 | 100 | | | | |
| *Eriophyllum lanatum* | | 60 | .1 | 75 | .2 | 100 | .1 | 60 |
| *Bromus tectorum** | | 60 | | | .2 | 100 | 1.7 | 100 |
| *Stipa thurberiana* | | | .1 | 75 | .4 | 80 | .7 | 100 |
| *Chaenactis douglasii* | | | | | | 20 | .3 | 100 |
| *Astragalus* sp. | | | | 25 | | 80 | .2 | 100 |
| *Cryptantha ambigua** | | 20 | | 50 | .1 | 80 | .3 | 100 |
| *Chrysothamnus nauseosus* | | 40 | .2 | 100 | | 20 | .2 | 60 |
| *Festuca octoflora** | | | | | | | | |
| *Sitanion hystrix* | | 20 | | | | | .1 | 40 |
| *Erigeron linearis* | | 60 | | | .1 | 80 | .2 | 80 |
| *Purshia tridentata* | | | | | .6 | 100 | .1 | 60 |
| | | | | | (3.5) | (100) | | |
| *Chrysothamnus viscidiflorus* | .3 | 80 | .2 | 100 | .1 | 100 | .4 | 60 |
| *Collomia grandiflora** | | | | | | 80 | | |
| *Mentzelia albicaulis** | | | | | | | .1 | 80 |
| *Montia perfoliata** | .3 | 60 | | | | 20 | | |
| *Eriogonum ochrocephalum* | | | | 75 | | 20 | | 60 |
| *Astragalus lectulus* | | | | | | 60 | | |
| *Stipa comata* | | | | | | | | |
| *Eriogonum sphaerocephalum* | | | | | | 20 | | |
| *Linanthus harknessii** | | | | 25 | | | .2 | 80 |
| *Eriogonum baileyi** | | | | 25 | | 60 | | |
| *Eriogonum umbellatum* | | | | | | 80 | | |
| *Penstemon cinereus* | | | | | .1 | 80 | | |
| Other perennial herbs[2] | .1 | | .1 | | .1 | | 1.4 | |
| Other perennial shrubs[3] | .3 | | 1.7 | | | | | |
| Total perennial herbs | 20.5 | | 17.0 | | 15.1 | | 10.1 | |
| | | | | | (9.6) | | | |
| Total shrubs and suffrutescents | 8.0 | | 7.5 | | 1.6 | | 4.8 | |
| | | | | | (4.5) | | | |

[1] Cover recorded for species having at least 0.1-percent cover in a single association.
Constancy recorded for species attaining 80-percent constancy or more in at least one association.
Species characteristics in parentheses indicate association variants.
Species with constancy but not cover, indicates presence in insufficient quantity to provide cover estimates.

[2] Mostly *Carex filifolia* in the *Juniperus/Artemisia/Agropyron-Chaenactis* association; variable in others.

[3] Mostly *Tetradymia canescens* in the *Juniperus/Artemisia/Festuca*, *Juniperus/Artemisia/Festuca-Lupinus*, and *Juniperus/Artemisia/Agropyron-Astragalus* associations; *Tetradymia canescens* and *Leptodactylon pungens* in the *Juniperus/Artemisia-Purshia* association.

* Annuals.

| Association |
|---|
| *Juniperus/Artemisia/Festuca* |
| *Juniperus/Artemisia/Festuca-Lupinus* |
| *Juniperus/Festuca* (*Purshia* variant) |
| *Juniperus/Artemisia/Agropyron-Chaenactis* |
| *Juniperus/Artemisia/Agropyron* |
| *Juniperus/Agropyron* (*Purshia* variant) |
| *Juniperus/Artemisia-Purshia* |
| *Juniperus/Agropyron-Festuca* |
| *Juniperus/Artemisia/Agropyron-Astragalus* |

| Association | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Juniperus/ Artemisia/ Agropyron* | | *Juniperus/ Agropyron* | | *Juniperus/ Artemisia- Purshia* | | *Juniperus/ Agropyron- Festuca* | | *Juniperus/ Artemisia/ Agropyron- Astragalus* | |
| Cover | Constancy | Cover | Constancy | Cover | Constancy | Cover | Constancy | Cover | Constancy |
| 10.0 | 100 | 43.0 | 100 | 6.6 | 100 | 32.0 | 100 | 27.7 | 100 |
| 8.5 | 100 | .9 | 100 | 8.2 | 100 | 3.0 | 100 | 6.7 | 100 |
| | | | (100) | | | | | | |
| .4 | 60 | 1.7 | 100 | 2.5 | 100 | 2.3 | 100 | | |
| 9.2 | 100 | 5.0 | 100 | .9 | 100 | 3.2 | 100 | 7.0 | 100 |
| 1.3 | 100 | .7 | 100 | .2 | 60 | 1.4 | 100 | .9 | 100 |
| | | .3 | 100 | .1 | 100 | .5 | 100 | .5 | 100 |
| .3 | 100 | | 50 | | | | | | |
| .1 | 60 | | | | | | 20 | | 17 |
| .1 | 100 | .2 | 100 | .2 | 100 | .1 | 100 | .1 | 100 |
| .6 | 100 | | 34 | | 20 | | | | |
| .1 | 100 | .1 | 100 | .2 | 100 | | 100 | | 84 |
| | | | 84 | 1.0 | 100 | | 20 | | 50 |
| | | | 17 | | | .2 | 60 | | |
| .1 | 20 | .2 | 100 | | 20 | .3 | 80 | .4 | 100 |
| | | | | | | .1 | 80 | | |
| | | | | | | .1 | 20 | | |
| | | .1 | 68 | | 40 | .5 | 80 | | 34 |
| 1.7 | 100 | .4 | 100 | 2.7 | 100 | .1 | 80 | .5 | 100 |
| 2.0 | 80 | .2 | 100 | .3 | 60 | .5 | 100 | | 50 |
| | | | | | | | 20 | | |
| | | .3 | 100 | | 60 | .3 | 80 | .2 | 100 |
| | 20 | .1 | 100 | .6 | 100 | | 100 | .1 | 100 |
| 1.1 | 100 | | 34 | .2 | 40 | .3 | 60 | | |
| .6 | 100 | | 34 | | | | | .1 | 34 |
| .1 | 40 | | | .2 | 100 | | 40 | | 17 |
| | 20 | .1 | 100 | .1 | 100 | | | .1 | 100 |
| | | .1 | 100 | 5.5 | 100 | | | .3 | 34 |
| | | (6.7) | (100) | | | | | | |
| | | .4 | 84 | 1.5 | 100 | .4 | 60 | .6 | 50 |
| | | | 68 | .1 | 100 | | 20 | | 17 |
| | | | | .5 | 100 | | 20 | | |
| | | | | .1 | 100 | | | | |
| | | | | | | .1 | 100 | | |
| | | | 17 | | | | | .1 | 100 |
| | | | | | 80 | | 20 | | |
| | | | 34 | | | .8 | 100 | | |
| | 20 | | | | 20 | | 80 | | |
| | | .1 | 68 | | 20 | | | .1 | 84 |
| | 20 | .1 | 34 | | 20 | | | | 17 |
| | | | 17 | | | .1 | 20 | | |
| .1 | | .2 | | .1 | | .3 | | .3 | |
| | | | | .8 | | | | .2 | |
| 14.3 | | 9.1 | | 4.6 | | 9.8 | | 9.6 | |
| 9.6 | | 1.4 | | 16.2 | | 4.6 | | 7.8 | |
| | | (8.0) | | | | | | | |

Table 5.—Mean density counts (number per 0.02 acre) and heights (feet) of shrubby and suffrutescent species in nine associations in the central Oregon juniper zone

| *Artemisia tridentata* | | *Purshia tridentata* | | *Chrysothamnus nauseosus* | | *Chrysothamnus viscidiflorus* | | *Eriogonum sphaerocephalum* | | *Eriogonum microthecum* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Height | Number | Height | Number | Height | Number | Height | Number | Height | Number | Height |
| 104 | 1.29 | | | 2 | 1.09 | 55 | 1.24 | | | | |
| 44 | 1.17 | | | 3 | 1.73 | 7 | .78 | | | 4 | 0.69 |
| 29 | 1.17 | 4 | 3.26 | 1 | 2.10 | 10 | .44 | 2 | 0.45 | | |
| (5) | | (6) | (3.78) | | | | | | | | |
| 26 | 1.32 | 1 | .90 | 4 | .99 | 10 | .86 | | | | |
| 26 | 1.95 | | | 4 | 2.03 | | | | | | |
| 4 | 1.32 | 2 | 1.93 | 1 | 1.75 | 8 | .66 | 1 | .60 | | |
| (3) | 1.82 | (7) | (2.69) | | | | | | | | |
| 34 | 1.79 | 13 | 2.49 | 3 | 1.74 | 17 | 1.40 | | | | |
| 17 | 1.52 | | | 2 | 1.73 | 6 | .71 | 17 | .69 | 4 | .72 |
| 26 | 1.26 | 1 | 2.90 | | | 9 | .89 | | | | |

## *Juniperus/Artemisia/Festuca* Association

This association occurred on northwest- to northeast-facing slopes with loamy Chestnut soils. The vegetation was relatively dense with a perennial herbaceous foliage cover of 20.5 percent (fig. 3), the greatest amount measured in any of the entities. Soil surface occupied by perennial herbs, organic matter in the A horizon, and total nitrogen in the A horizon, 7.4, 4.78, and 0.21 percent, respectively, was also greater in this unit (table 3). Bare soil surface, 22.1 percent, was less than in the other units. Although available soil moisture storage capacity in the 2- to 14-inch soil zone, 1.41 inches, was less than in some of the other units (table 3), its effectiveness was increased by loamy and clayey surface and subsoils, rockiness of the solum, and reduced insolation on the northerly aspect.

*Juniperus occidentalis*, *Artemisia tridentata*, and *Festuca idahoensis* were the most characteristic species of the plant community. Respectively, they provided 12.0-, 7.4-, and 10.8-percent foliage cover. *Agropyron spicatum*, the next most abundant plant, had a foliage cover value of 5.3 percent and provided a characteristic bunchgrass aspect (fig. 4). The combined foliage cover value of this species and *Festuca idahoensis* was at least 20 percent greater than for the same species in any of the other entities. *Poa secunda* achieved its maximum development is this association as compared with the other associations.

Mature plants of A. tridentata provided 7.4-percent foliage cover and attained an average maximum height of 1.29 feet. Average density of the species was 104 plants per 0.02 acre, more than double its density in other units (table 5). Density of Chrysothamnus viscidiflorus, more than 70 percent higher than in other units, was the only other primary diagnostic characteristic of the shrub stratum.

*Astragalus* sp. was the most abundant forb with average foliage cover of 1.4 percent. Although the 100-percent constancy of this species was the same in the *Juniperus /Artemisia/ Agropyron* association, its cover value was nearly five times greater. *Agoseris* sp. had low cover, 0.4 percent, but it was present in all stands, a characteristic exclusive to this unit.

This association occurred with only one soil, a Chestnut loam developed from rhyolitic-andesitic colluvium (series I—see Appendix 2 for soils description). Solum depth was 30 inches. The surface horizon was a loam. The relatively high organic matter content in the surface horizon imparted a very dark brown color. The surface horizon of soils in the other ecosystems were not this dark.

The heaviest part of the B horizon was clay and had strong, blocky structure, very hard when dry and firm when moist. Ordinarily, rooting depth would be restricted because of these subsoil characteristics, but in this case, 50 percent of the solum volume was occupied by large stones which allowed roots to penetrate deeper than might be expected (fig. 5).

## *Juniperus /Artemisia /Festuca - Lupinus* Association

This unit occurred on north- to northeast-facing slopes with azonal soils which supported less luxuriant vegetation than the previous association. Perennial herbaceous cover was 17.0 percent as compared with 20.5 percent in the previously described unit. *Juniperus occidentalis*, *Artemisia tridentata*, and *Festuca idahoensis* also characterized the vegetational component of this ecosystem but differed quantitatively from the *Juniperus/Artemisia /Festuca* association. Cover of these species was 12.3, 5.1, and 10.4 percent, respectively (table 4). Cover of *A. tridentata* provided the most striking difference, nearly 30 percent less in this association. Average maximum height of mature *A. tridentata* was 1.17 feet. Density of the species was less than half the density occurring in the first described unit (table 5).

Figure 3
Stand representative of the *Juniperus/Artemisia/Festuca* association, illustrating relatively rich and dense vegetation.

Figure 4
Detail of the understory vegetation of the *Juniperus/Artemisia/Festuca* association. The vegetational aspect is one of large, vigorous plants of *Agropyron spicatum*, although *Festuca idahoensis* is dominant on a cover basis.

Figure 5
Profile of soil series I occurring with the *Juniperus/Artemisia/Festuca* association. Stoniness in the heavy, strongly developed B horizon allows deep root penetration. Compare with figure 18.

*Juniperus occidentalis* was patchy, occurring as clumps of several trees throughout the association (fig. 6). The comparative paucity of this species may be partly due to old fires. Charred tree trunks and roots were common wherever the entity was observed.

*Agropyron spicatum* provided only 1.5-percent cover in contrast to 5.3 percent in the *Juniperus/Artemisia/Festuca* association found on Chestnut soils. Foliage cover of *Poa secunda* was also less, 1.0 percent. *Koeleria cristata* had a cover value of 0.8 percent, a tenth greater than in any other association.

*Lupinus* sp. provided the most striking vegetational difference between this association and its counterpart on Chestnut soils. Here, the species was present in all stands and had a cover value of 2.3 percent but was absent in the previous association. *Phlox douglasii* and *Erigeron filifolius* provided little cover, 0.3 percent each, but they were present in all stands as compared with 40-percent constancy in the *Juniperus/Artemisia/Festuca* association.

*Eriogonum microthecum* was especially diagnostic of this unit. Cover and constancy of the species was 0.3 and 100 percent, respectively. The species occurred in only one other unit, the *Juniperus/Agropyron-Festuca* association, where its cover value was only 0.1 percent and constancy was only 20 percent.

The soil associated with the *Juniperus/Artemisia/Festuca-Lupinus* association was a shallow (16 inches) sandy loam Regosol overlying mixed alluvium and unconsolidated rhyolitic and andesitic stones (series II—shallow, nonstony phase). Pentagonal configurations were characteristic of the soil surface when it was dry (fig. 7). Specific reasons for the development of these configurations are not known, but they were probably associated with frost action. Some of the blocks were completely tipped over, with moss and small ephemeral plants persisting on what was once the top of the block.

The entire solum was a sandy loam with roots abundantly distributed throughout the profile (fig. 8). The available water storage capacity in the 2- to 14-inch zone was 1.98 inches, at least 20 percent more than in the same soil zone of azonal soils in other units. Total nitrogen in the A horizon was 0.10 percent. The underlying material was highly variable and loose, allowing relatively deep root penetration. Pumice sands contributed 30 percent to the solum volume.

## *Juniperus/ Festuca* Association

This association occurred on the lower portions of northwest-facing slopes with Brown soils having loam textures. Perennial herbaceous cover was 15.1 percent. Shrub cover was scant (1.6 percent), exceeding only the *Juniperus/Agropyron* association.

*Juniperus occidentalis* and *Festuca idahoensis* were the most abundant species of the association. *Juniperus occidentalis* had a foliage cover value of 76.7 percent, nearly twice as much as any other association. The high cover value and the close spacing of individual trees gave the area an aspect of a relatively dense forest (fig. 9). Foliage cover of *Festuca idahoensis* was 10.8 percent, equaling that of the *Juniperus/Artemisia/Festuca* association. However, individual plants were relatively small and did not have the robust, vigorous appearance usually characteristic of the species (fig. 10).

*Agropyron spicatum*, *Poa secunda*, and *Koeleria cristata* had 100-percent constancies but were less characteristic perennial grasses of this association. Cover values of these species were 1.6, 0.9, and 0.3 percent, respectively. Perennial forbs were minor parts of the vegetational component of this association.

*Purshia tridentata* was the most diagnostic species in the shrub layer. Although cover and density values were low, 0.6 percent and 4 plants per 0.02 acre, respectively, mature plants were tall (3.26 feet). This height was exceeded only in the *Purshia* variant of the association

Figure 6
Stand representative of the *Juniperus / Artemisia / Festuca-Lupinus* association. The clumpiness and paucity of the *Juniperus occidentalis* component is associated with past fires.

Figure 7
Detail of the soil surface and understory vegetation occurring with the *Juniperus/Artemisia/Festuca-Lupinus* association. The pentagonal configurations on the soil surface are characteristic of the soils of this unit.

Figure 8
Soil profile of series II—shallow, nonstony phase occurring with the *Juniperus/Artemisia/Festuca-Lupinus* association. Plant roots are abundantly distributed throughout the solum. Different phases of this same series are found with three other associations, *Juniperus/Artemisia/Agropyron-Chaenactis*, *Juniperus/Artemisia-Purshia*, and *Juniperus/Agropyron-Festuca*.

being discussed (table 5). Cover and density of *Artemisia tridentata* were greater (0.9 percent and 29 plants per 0.02 acre, respectively) than *P. tridentata*, but the average maximum height of mature plants of *A tridentata* was much less (1.17 feet).

The *Juniperus/Festuca* association occurred with two soil series (series III and series IV). Both were Brown loams but had developed from different materials. Series III developed from friable, tuffaceous material. Series IV developed from aeolian sands and small, loosely packed rhyolitic and andesitic colluvial stones.

Some internal characteristics of both soils were similar. Available water storage capacity in the 2- to 14-inch soil zone was 1.81 inches. Organic matter content and total nitrogen of the A horizon was 3.91 and 0.17 percent, respectively. In contrast to the other units, these two characteristics were exceeded only in the Chestnut soil occurring with the *Juniperus/Artemisia/Festuca* association.

Subsoil textures and solum depths were different, however, between series III and series IV. Series III had a clayey subsoil not too strongly developed. The solum of this series was only 18 inches deep, but the friable underlying material allowed root penetration which compensated, to some extent, the relatively shallow depth (fig. 11). Series IV had loamy subsoils and the solum was 28 inches deep. The deeper solum and coarser subsoil texture of series IV apparently affected plant growth and distribution in a way similar to the shallow, clayey subsoil and friable parent material of series III.

*Purshia* variant: *Juniperus/Festuca* association.—The *Purshia* variant of the *Juniperus/Festuca* association occurred on southeasterly slopes with the very stony phase of soil series III. Vegetational characteristics were the same as the association except for cover, mature plant height, and density of *Purshia tridentata*; cover of *Festuca idahoensis*; and density of *Artemisia tridentata*.

Cover of *P. tridentata* increased from 0.6 percent in the *Juniperus/Festuca* association to 3.5 percent in its variant. Average maximum height of mature *P. tridentata* plants was 3.78 feet, approximately 0.5 foot higher than in the association. Density of the species increased from four plants to six plants per 0.02 acre, but the crowns of the individual plants in the variant were wide (fig. 12).

Cover of *Festuca idahoensis* decreased from 10.8 percent in the association to 5.3 percent in its variant. Density of *Artemisia tridentata* decreased from 29 to 5 plants per 0.02 acre but cover and mature plant height were the same. As with *Purshia tridentata*, individual plant crowns of *A. tridentata* in the variant were wide as compared with crown width of the species in the association.

Visible soil morphological characteristics of the soil occurring with the variant are the same as the soil occurring with the association except for stoniness of the solum (fig. 13). Relatively large rhyolitic and andesitic stones occupied 50 percent of the profile volume in the soil phase as compared with only 5 percent in the soil series. Other characteristics determined by laboratory analyses were quite different (table 3). Available water storage capacity in the 2- to 14-inch soil zone of the phase was 2.14 inches, 15 percent more than the same soil zone in the series was capable of storing. Organic matter and total nitrogen in the A horizon were approximately 37 and 41 percent less, respectively, in the phase as compared with the series. Regardless of these strong soil differences between the association and its variant, the stronger vegetational similarities warranted keeping the variant as a part of the association.

Figure 9
Stand representative of the *Juniperus/Festuca* association. This association had the highest *Juniperus occidentalis* cover in study area.

Figure 10
Detail of the understory vegetation of *Juniperus/Festuca* association. Individual plants of *Festuca idahoensis* are less robust than is characteristic for the species.

Figure 11
Profile of soil series III occurring with the *Juniperus/Festuca* association. The tuffaceous, parent material becomes friable when wet, allowing root penetration.

## *Juniperus/Artemisia/Agropyron-Chaenactis* Association

This unit occurred on northwest- to northeast-facing slopes. The related soil was the same series and type as occurred with the *Juniperus/Artemisia/Festuca-Lupinus* association but represented a moderately deep, extremely stony phase.

Perennial herbaceous cover was more than 30 percent less than in previous units. *Agropyron spicatum* was the most abundant herbaceous species, with an average foliage cover of 3.7 percent. These characteristics indicate environmental conditions more xeric than existed in previously described units. *Juniperus occidentalis* had an average foliage cover of 46.0 percent and was fairly evenly spaced to give a savanna aspect (fig. 14). *Artemisia tridentata* was the most abundant shrub. Cover of the plant was 4.1 percent, maximum mature plant height was 1.32 feet, and plant density was 26 plants per 0.02 acre. *Chaenactis douglasii* had 100-percent constancy, an exclusive characteristic of this association.

*Festuca idahoensis, Poa secunda, Koeleria cristata,* and *Stipa thurberiana* had 100-percent constancies. Cover of *F. idahoensis* was only 1.9 percent, a reduction of at least 73 percent as compared with previously described units.

Some annual species provided important diagnostic characteristics in this association. *Collinsia parviflora* had 100-percent constancy and 0.6-percent cover, equaled only in the *Juniperus/Artemisia/Festuca* association. *Linanthus harknessii* had 0.2-percent cover, greater than in any of the other units. *Bromus tectorum* had an average cover of 1.7 percent, exceeded only in the *Juniperus/Artemisia-Purshia* association.

Shrubs other than *Artemisia tridentata* had little value for characterizing this association on the basis of dominance or constancy if the species were considered individually. *Chrysothamnus nauseosus, Purshia tridentata,* and *Chrysothamnus viscidiflorus* had constancy ratings of only 60 percent each and cover values of 0.2, 0.1, and 0.4 percent, respectively. The most abundant of these three species was *C. viscidiflorus*, with 10 plants per 0.02 acre. Mature plants of *C. nauseosus* were the tallest of these species, 0.99 foot. However, the characteristic relationships among these species, as compared with the same among species relationships in other entities, provided diagnostic features specific to this ecological unit. None of the other associations had even similar alliances among these species.

The soil occurring with this association was a moderately deep (26 inches), sandy loam Regosol, overlying fractured basalt bedrock or closely packed basalt stones (series II—moderately deep, extremely stony phase). It differed visually from the soil occurring with the *Juniperus/Artemisia/Festuca-Lupinus* association in solum depth, solum stoniness, and nature of the underlying material. The solum of the soil component of the *Juniperus/Artemisia/Agropyron-Chaenactis* association was 10 inches deeper and containea 50 percent more stones. Only 10 percent of the underlying material in this soil was capable of supplying moisture and available nutrients to plants as compared with 50 percent of the same material in the soil supporting the *Juniperus/Artemisia/Festuca-Lupinus* association.

Roots in this soil were abundantly distributed throughout the profile (fig. 8). Available water storage capacity in the 2- to 14-inch zone was 0.87 inch, less than half the capacity of the shallow, nonstony phase supporting the *Juniperus/Artemisia/Festuca-Lupinus* association. This was primarily the result of the greater volume of stones in the solum. Organic matter content and total nitrogen of the A horizon were 1.59 and 0.08 percent, respectively, slightly less than the shallow nonstony phase. The soil surface was 52.3-percent bare and had 5.2 percent of its area occupied by root crowns of herbaceous perennials (fig. 15).

Figure 12
Stand representative of the *Purshia* variant: *Juniperus/Festuca* association. Density of *Purshia tridentata* is low, but individual plant crowns are wide. The species is in the center of the picture.

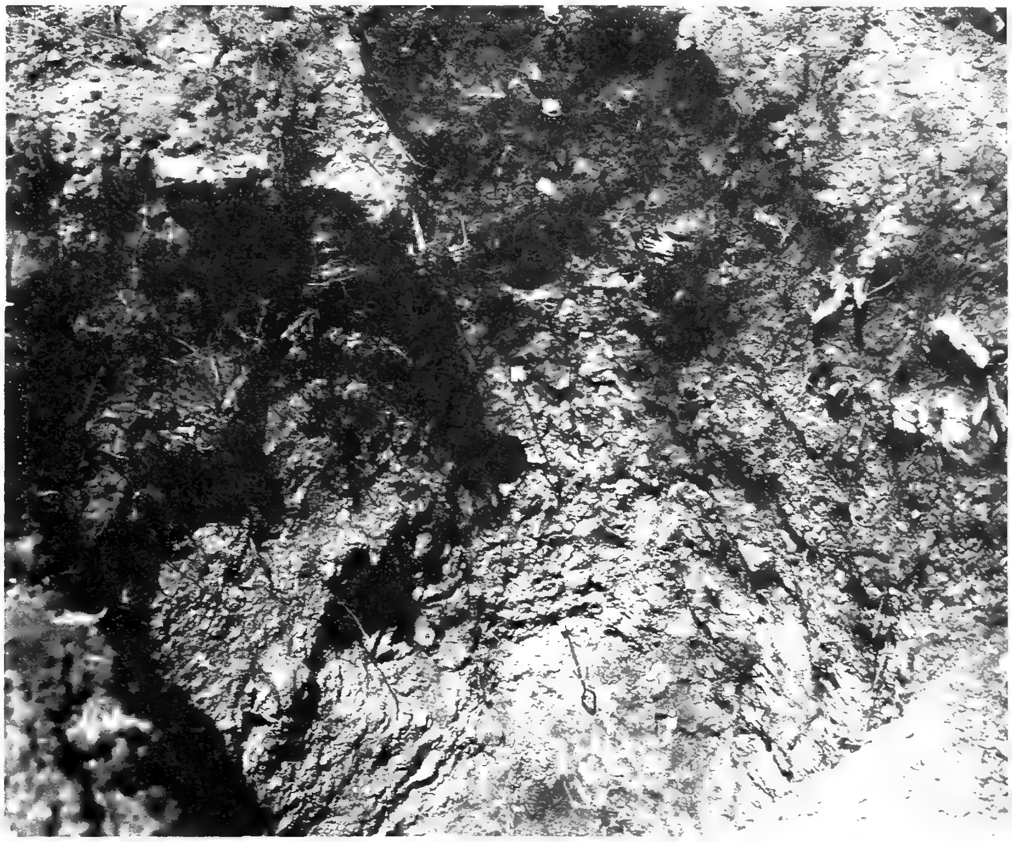

Figure 13
Soil profile of series III—very stony phase, supporting the *Purshia* variant: *Juniperus/Festuca* association. Rhyolitic and andesitic stones occupy 50 percent of the profile volume.

Figure 14
Stand representative of the *Juniperus/Artemisia/Agropyron-Chaenactis* association. *Juniperus occidentalis* is fairly evenly spaced, providing the characteristic savanna aspect of the juniper zone.

Figure 15
Detail of the soil surface and understory vegetation related to *Juniperus/Artemisia/Agropyron-Chaenactis* association. Approximately 52.3 percent of the soil surface is bare.

## *Juniperus/Artemisia/Agropyron* Association

This association occurred on undulating uplands with strongly developed Brown soils. *Juniperus occidentalis*, *Artemisia tridentata*, and *Agropyron spicatum* characterized the vegetational component of this association (fig. 16). Cover of *J. occidentalis* averaged 10 percent. However, the trees were unevenly distributed, occurring in small clumps throughout the area. This situation was similar to the grouping of the trees in the *Juniperus/Artemisia/Festuca-Lupinus* association. In both cases, wildfire appears to have been a major factor determining tree survival and distribution. Charred stumps and logs on the surface and roots in the soil were fairly common.

*Artemisia tridentata* attained maximum stature in this unit as compared with the other classified units. Average maximum height of mature plants was 1.95 feet. Foliage cover of the species was 8.5 percent. Both of these characteristics were at least 10 percent greater than in any of the other associations. *Chrysothamnus nauseosus* was the only other shrub measured in the association. The 1.1-percent cover of the species was at least 70 percent greater than in other associations.

*Agropyron spicatum* also reached maximum development in this unit as compared with the other associations. Cover of the species was 9.2 percent, nearly a fourth more than in any other unit. Most of the plants were robust and widely spaced, prominent characteristics of the association (fig. 17).

*Stipa thurberiana* was the next most abundant herb in the *Juniperus/Artemisia/Agropyron* association. Although constancy of the species (80 percent) was exceeded in other units, its cover value (2 percent) was at least 35 percent greater than in other units. *Poa secunda*, *Festuca idahoensis*, and *Sitanion hystrix* were the only other perennial grasses encountered in the sample plots. Cover of these species was 1.3, 0.4, and 0.1 percent, respectively. *F. idahoensis* was found mostly in the deep shade of shrubs or trees.

In general, there was a paucity of perennial forbs. *Lomatium triternatum* was the most prevalent with 0.6-percent cover. Including this species, only eight forbs were identifiable when the association was examined.

An annual grass, *Bromus tectorum*, was fairly abundant. It occurred throughout the area with 1.7-percent cover. *Festuca octoflora* had a cover of 0.6 percent and constancy of 100 percent, considerably more than in any of the other associations. Other annuals were present but not as characteristic as these species.

Two soil series occurred with the *Juniperus/-Artemisia/Agropyron* association (series V and series VI). Both were strongly developed Brown loams but had formed from different parent materials. Series V developed from river- and lake-laid sediments; series VI developed from relatively loose loess and very fine sands. The parent material of both soils contained numerous, partially decomposed, small basalt fragments and was 26 and 13 inches, respectively, below the surface of the two soils. Discontinuous caliches occurred in the lower B horizons of the two soils. Small stones occupied 5 percent of the volume of the solum of both soils.

The primary internal characteristics visibly different between these series were position, thickness, and texture of the heaviest portion of the B horizon. In series V, this soil layer began approximately 15 inches below the soil surface, was 8 inches thick, and had clay texture. The same horizon of series VI started at an average of 8 inches below the soil surface, was 2 inches thick, and had clay loam texture.

This heavy subsoil horizon of these soils was similar to the same horizon in series I of the *Juniperus/Artemisia/Festuca* association. In all these soils, this horizon was strongly structured, very hard, and firm. However, the paucity of stones in the soils of the *Juniperus/Artemisia/Agropyron* association, together with the textural, structural, and consistency characteristics, restricted root penetration (fig. 18). In series

Figure 16
Stand representative of the *Juniperus / Artemisia / Agropyron* association characterized by clumps of *Juniperus occidentalis* and maximum development of *Artemisia tridentata* and *Agropyron spicatum.*

Figure 17
Detail of the herbaceous and shrubby components of the *Juniperus / Artemisia / Agropyron* association. Wide spacing and high cover of *Agropyron spicatum* are diagnostic features of the area.

Figure 18
Soil profile of series V supporting the *Juniperus/Artemisia/ Agropyron* association. The strongly structured, very hard, and firm B horizon restricts root penetration. Compare with figure 5.

V no roots were found below the heaviest subsoil horizon. The thinness and slightly coarser texture of this horizon in series VI allowed some roots to penetrate to deeper soil material. In series I, roots were common to abundant throughout the solum.

Other internal characteristics of series V and series VI were the same. Available water storage capacity in the 2- to 14-inch zone was 2.31 inches. This quantity was greater than in any of the other units but was less effective because of the topographic position of this unit and subsoil characteristics. Organic matter and total nitrogen of the A horizon were 1.50 and 0.08 percent, respectively. These quantities were less than occurred in any of the other zonal soils which occurred with the *Juniperus/Artemisia/Festuca, Juniperus/Festuca, Juniperus/Agropyron,* and *Juniperus/Artemisia/Agropyron-Astragalus* associations.

## *Juniperus/ Agropyron* Association

This association occurs on east- to northeast-facing slopes with Brown sandy clay loam soils. The shrubby layer was nearly absent in this unit (fig. 19). Density of *Artemisia tridentata* was only four plants per 0.02 acre, the least number counted in any of the units (table 5). The 0.9-percent cover of the species provided 64 percent of the total 1.4-percent shrub cover. This total shrub cover value was less than in all other associations.

An unusual relationship occurred between *Agropyron spicatum* and *Festuca idahoensis.* Comparatively, *A. spicatum* was more abundant on drier sites such as south- or west-facing slopes, but *F. idahoensis* was more abundant on the more mesic sites of north- and east-facing slopes. In this association, however, *A. spicatum,* with 5.0-percent cover, dominated the herbaceous layer and *F. idahoensis* had only one-third as much cover and was a relatively minor species (fig. 20). The abundance of stones on and in the soil, as it affected soil moisture, temperature, and plant-supporting area of the association, probably contributed to this relationship.

*Juniperus occidentalis* had a cover of 43.0 percent. The trees were fairly evenly distributed and provided an aspect similar to the *Juniperus/Artemisia/Agropyron-Chaenactis* association.

Few perennial forbs occurred in this association and those present were in limited amounts. *Poa secunda, Koeleria cristata, Achillea millefolium, Phlox douglasii, Stipa thurberiana, Astragalus* sp., and *Erigeron linearis* each had 100-percent constancy rating. However, the combined cover of all these species was only 2.0 percent which consists mostly of *P. secunda* with 0.7-percent cover.

Associated with the *Juniperus/Agropyron* association were two soil series and a phase of one of these series (series VII, series VIII, and series VII—shallow phase). Series VII and its shallow phase occurred with the association. Series VIII occurred with the *Purshia* variant subsequently discussed.

Series VII was a sandy clay loam developed from a relatively thin layer of rhyolitic-andesitic colluvium overlying indurate tuffaceous material (fig. 21). The underlying stratum was unrelated to the soil but affected plant growth by restricting root penetration.

With the exception of solum depth, which changes horizon thickness, characteristics of the series and its stony phase were very similar. Solum depth of the series was 40 inches and of the phase was 20 inches. The heaviest part of the subsoil was a clay loam with moderate to strong prismatic and blocky structure, very hard when dry, becoming friable when moist. The moist friability of this part of the soil and the high stone content (40 percent) permitted good root penetration. This was in contrast to the subsoil conditions in series V of the *Juniperus/Artemisia/Agropyron* association. In this soil, the moist consistency of the heaviest part of the subsoil was firm, which mechanically restricted root penetration.

Figure 19
Stand representative of the *Juniperus/Agropyron* association. The shrub layer was nearly absent in this unit.

Figure 20
Detail of the soil surface and herbaceous vegetation related to *Juniperus/Agropyron* association. *Agropyron spicatum* dominates the herbaceous layer of this north-slope area. The many large stones on the soil surface are specific to this unit.

Figure 21
Soil profile of series VII occurring with the *Juniperus/Agropyron* association. The indurate material underlying the soil stops root growth and penetration.

The soil surface in the *Juniperus /Agropyron* association was 51.1-percent bare, the highest percentage of any of the zonal soils. Root crowns of perennial herbs occupied 3.2 percent of the soil surface, less than any of the other zonal soils. Available water storage capacity in the 2- to 14-inch soil zone was 1.34 inches. Organic matter content and total nitrogen of the A horizon were 2.12 and 0.10 percent, respectively.

*Purshia* variant: *Juniperus/Agropyron* association.—The *Purshia* variant of the *Juniperus / Agropyron* association occurred on southeasterly slopes with a Brown loam soil (series VIII). Vegetational characteristics of the association and the variant were the same, except for the strong development of *Purshia tridentata* in the variant (fig. 22). Here, the species attained the maximum cover of any of the units measured (6.7 percent). This was almost twice the cover value of the species in the *Purshia* variant of the *Juniperus/Festuca* association and nearly 20 percent more than in any of the associations. Density of *P. tridentata* was seven plants per 0.02 acre. Average maximum height of mature plants was 2.69 feet, approximately 1 foot shorter than in the *Purshia* variant of the *Juniperus /Festuca* association.

Soil factors and slope aspect seemed to have primary influence on the development of *P. tridentata* in the *Purshia* variant of the *Juniperus/Agropyron* association. The soil was a relatively shallow (20 inches) loam developed from rhyolitic-andesitic colluvium. The stony parent material was loose and had sandy clay material between the large stones. The densest portion of the subsoil was a strongly structured, hard, and firm clay. Relatively large stones, comprising 40 percent of the solum, modified the strongly developed clayey subsoil and allowed deeper root penetration than existed in series VII associated with the *Juniperus /Agropyron* association (fig. 23).

Even though the association and its variant occurred with different soil classes and slopes, similar vegetational characteristics, other than *P. tridentata*, and similarity of some soil characteristics warranted classifying the variant as a part of the association.

## *Juniperus/Artemisia-Purshia* Association

The vegetational component of this association was characterized principally by a conspicuous shrub layer (fig. 24). Total shrub cover in the unit (16.2 percent) was almost twice as much as the amount of shrub cover in other units. *Artemisia tridentata* and *Purshia tridentata* shared importance with 8.2- and 5.5-percent cover, respectively. Mature plant height of *A. tridentata* averaged 1.79 feet. These characteristics of *A. tridentata* were exceeded only in the *Juniperus/Artemisia/Agropyron* association where it attained its maximum stature in the units measured. Density of *P. tridentata*, 13 plants per 0.02 acre, was nearly twice as great as its density in the variants of the *Juniperus/Festuca* and *Juniperus/Agropyron* associations. Average maximum height of mature plants was 2.49 feet.

Herbaceous annuals were diagnostic of this association although they were inconspicuous in the general aspect. *Collinsia parviflora*, *Gayophytum lasiospermum*, *Bromus tectorum*, *Cryptantha ambigua*, *Collomia grandiflora*, *Mentzelia albicaulis*, and *Montia perfoliata* all had a constancy of 100 percent. Total cover of these annual species was 11 percent greater than total cover of perennial herbs. *Bromus tectorum* attained its maximum cover, 2.7 percent, in this association. Cover of *G. lasiospermum* (1 percent), *C. ambigua* (0.6 percent), *M. albicaulis* (0.5 percent), and *C. grandiflora* (0.1 percent), were also greater here than in any of the other units.

Figure 22
Stand representative of the *Purshia* variant: *Juniperus/Agropyron* association. *Purshia tridentata* attained its maximum cover on this site as compared with the other units.

Figure 23
Soil profile of series VIII supporting the *Purshia* variant: *Juniperus / Agropyron* association. The stony solum and loose parent material allow deep penetration of *Purshia tridentata* roots.

Figure 24
Stand representative of the *Juniperus/Artemisia-Purshia* association. *Artemisia tridentata* and *Purshia tridentata* share dominance in the shrub layer of this entity.

*Sitanion hystrix* attained maximum development in this association as compared with the others, with a constancy of 100 percent and a cover of 0.2 percent. It occurred in five other units but had minor constancy and cover characteristics. *Stipa comata* was also diagnostic with a constancy of 80 percent. The species occurred in only one other unit, the *Juniperus/Agropyron-Festuca* association, but had a constancy of only 20 percent.

Generally, herbaceous perennials were widely spaced and provided minor characterization value if considered individually. They were found mostly under the protective shade of shrubs (fig. 25). However, total cover of perennial herbs, 4.6 percent, was less than half the total perennial herb cover of any of the other associations.

The 6.6-percent cover of *Juniperus occidentalis* was another major diagnostic feature of this association. This cover value of the species was the least amount occurring in any of the units.

The soil occurring with the *Juniperus/Artemisia-Purshia* association was a deep, nonstony, sandy loam Regosol overlying a stony, loamy B2 horizon (series II—deep, nonstony phase). It differed principally from the previously described Regosols occurring with the *Juniperus/Artemisia/Festuca-Lupinus* and the *Juniperus/Artemisia/Agropyron-Chaenactis* associations in depth to the underlying material (45 inches), nature of the underlying material, and nonstoniness.

The entire solum was a structureless sandy loam (fig. 8). Internal drainage was very rapid, indicated by the mildly alkaline reaction (pH 7.5) of the deepest sandy material. Calcareous deposits, very common in soils of low-precipitation regions, were not found in this soil except in the buried horizon. These factors indicated a droughty soil environment, even though available water storage capacity in the 2- to 14-inch soil zone was 1.54 inches, a greater amount than some of the other soils (table 4). Most plant roots were concentrated in the upper 16 inches of the soil. Some roots, particularly large ones of the shrubs and trees, extended into the buried soil.

The amount of bare soil surface (55 percent) was more and the surface area occupied by root crowns of herbaceous perennials (3.1 percent) was less than occurred with any of the other azonal soils. The surface soil was extremely loose, requiring a minimum of traffic to create excessive disturbance (fig. 25). The comparatively low quantities of organic matter and total nitrogen in the A horizon, 1.05 and 0.06 percent, respectively, were the least amounts measured in any of the units.

## *Juniperus/Agropyron - Festuca* Association

This association was limited to east slopes and was characterized by large, mature *Juniperus occidentalis*, codominant status of *Agropyron spicatum* and *Festuca idahoensis* in the herbaceous layer, and specificity of *Eriogonum ochrocephalum* and *Eriogonum sphaerocephalum* (fig. 26).

*Juniperus occidentalis* had a cover of 32 percent, the second largest amount of the four associations on azonal soils. Cover of *A. spicatum* and *F. idahoensis* was 3.2 and 2.3 percent, respectively. Both plants had typical bunchgrass appearances and were spatially separated by considerable bare soil surface (fig. 27). The two species of *Eriogonum* had constancies of 100 percent, much greater than in the other associations where they occur. Cover of *E. sphaerocephalum* was 0.8 percent. Density of this suffrutescent species was 17 plants per 0.02 acre. The average maximum height of the mature plants was 0.69 foot. This species also occurred in the *Juniperus/Festuca* and *Juniperus/Agropyron* associations but in minute quantities. Cover of *E. ochrocephalum* was low, 0.1 percent. This species was present in three other units, the *Juniperus/Artemisia/Festuca-Lupinus*, the *Juniperus/Festuca*, and the *Juniperus/Artemisia/Agropyron-Chaenactis* associations, but did not occur on the observation plots.

Figure 25
Ground detail of the *Juniperus/Artemisia-Purshia* association. Perennial herbs are characteristically grouped under the protective shade of shrubs.

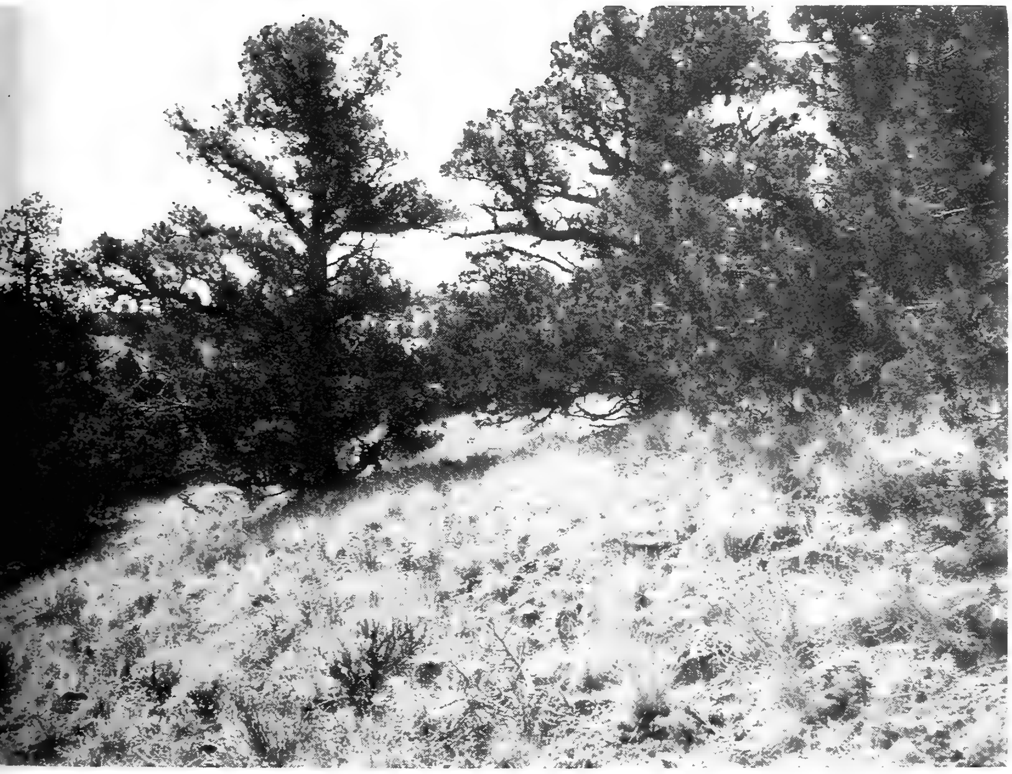

Figure 26
Stand representative of the *Juniperus / Agropyron-Festuca* association. Large, mature *Juniperus occidentalis* and the co-dominant status of *Agropyron spicatum* and *Festuca idahoensis* in the herbaceous layer characterize this entity.

Figure 27
Ground detail of the *Juniperus/Agropyron-Festuca* association. *Agropyron spicatum* and *Festuca idahoensis* share dominance in the herbaceous stratum. The conspicuous seedheads are *Koeleria cristata.* Several species occupied the same small space on the soil surface.

Most of the 4.6-percent shrub cover in this association was composed of *Artemisia tridentata* (3 percent). This cover value of the species was the least amount measured in any of the associations found with azonal soils.

Seedheads of *Koeleria cristata* provided a characteristic aspect in the herb layer when the association was studied (fig. 27). They were inconspicuous in other units even though cover of the species was often equaled or exceeded. *Poa secunda* had a relatively large cover value (1.4 percent) and was exceeded only in the *Juniperus / Artemisia /Festuca* association.

The soil supporting the vegetation of this entity was a moderately deep (23 inches), very stony, sandy loam Regosol overlying closely packed, cemented, rhyolitic-andesitic colluvium (series II—moderately deep, very stony phase). The primary difference between this soil and others of the same series as it influenced plant growth was the cementation of the underlying stratum. This stratum in the azonal soils occurring with the *Juniperus /Artemisia /Festuca-Lupinus*, the *Juniperus/Artemisia /Agropyron-Chaenactis*, and the *Juniperus /Artemisia-Purshia* associations was readily penetrable to plant roots.

The entire solum was a structureless sandy loam (fig. 8) and filled to approximately 35 percent with large stones. As a result, available water storage capacity in the 2- to 14-inch soil zone was 0.97 inch. Plant roots were mostly in the top 16 inches of the solum, although a few larger ones trailed on top of the cemented material and occasionally penetrated a soft spot. Organic matter and total nitrogen in the A horizon were 1.32 and 0.7 percent, respectively, exceeding only the soil occurring with the *Juniperus/Artemisia -Purshia* association.

The soil surface had some characteristics specific to this unit. Approximately 54.7 percent of its area was bare. Root crowns of perennial herbs occupied approximately 4.1 percent of the soil surface area. These values were only slightly greater than occurred on the soil surface with the *Juniperus /Artemisia -Purshia* association. Characteristically, several species of herbaceous perennials occupied a single small space on the soil surface (fig. 27). In addition, pentagonal configurations occurred on the soil, but they were more weakly developed than those characteristic of the soil found with the *Juniperus/Artemisia /Festuca -Lupinus* association. These peculiar shapes often imparted a microaspect of accelerated erosion. Frost heaving, however, appeared to be the primary cause of this feature.

## *Juniperus/Artemisia/Agropyron -Astragalus* Association

This association occupied locations representing the most xeric conditions of the study area (fig. 28). It was characteristic of south- and southwest-facing slopes with loamy Brown soils. Although total cover of perennial herbs (9.6 percent) and shrubs (7.8 percent) were greater than in some associations, other plant factor and soil combinations indicate the relative xerism of the unit.

A primary characteristic of this unit as compared with the others was the complete absence of *Festuca idahoensis* in measured stands. The species was present but occurred only in dense, protective shade of *Juniperus occidentalis*, and was not found on the observation plots. Annual species were present, but they were generally less conspicuous than in other associations. One species, *Eriogonum baileyi*, attained its maximum constancy rating (84 percent) in this unit as compared with the others.

The vegetation in this association was characterized partly by the comparative amounts of *J. occidentalis*, *Artemisia tridentata*, and *Agropyron spicatum*. Cover of *J. occidentalis* averaged 27.7 percent. Mature trees were not

Figure 28
Stand representative of the *Juniperus/Artemisia/Agropyron-Astragalus* association. This site represents the most xeric conditions of the units described.

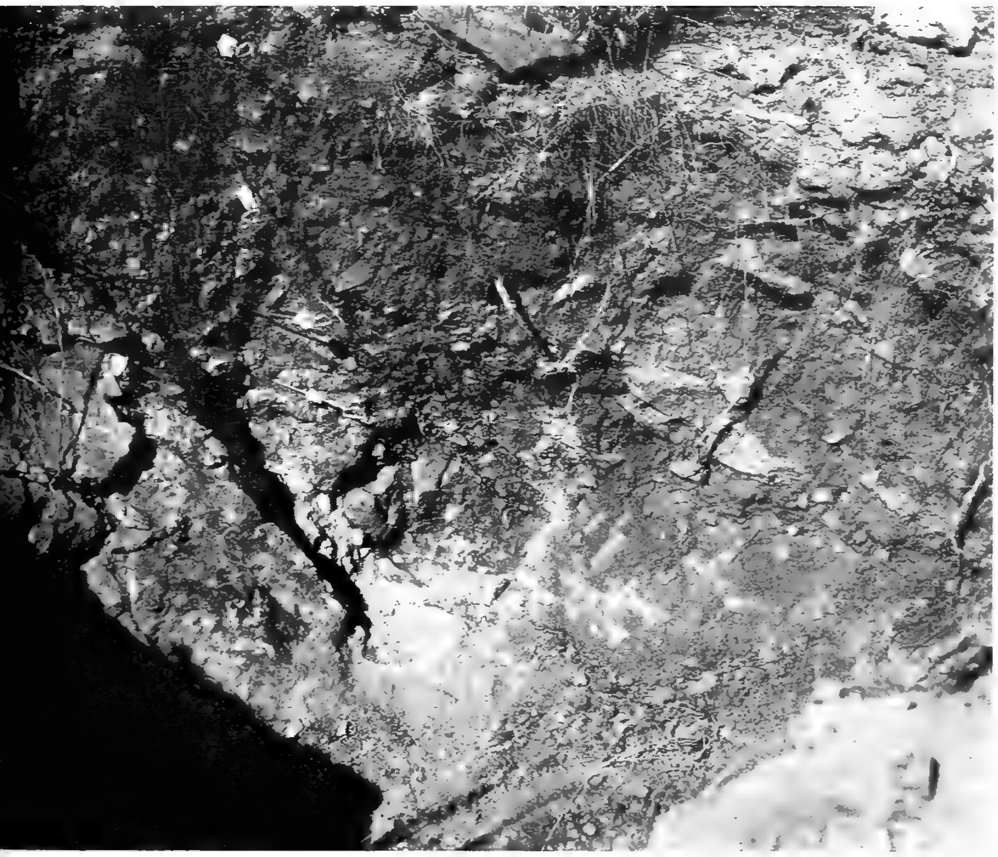

Figure 29
Soil profile of series IX occurring with the *Juniperus/Artemisia/Agropyron-Astragalus* association. Friability and stoniness of the clayey B horizon allows good root penetration. Compare with figure 18.

Figure 30
Detail of the soil surface and understory vegetation related to the *Juniperus/Artemisia/Agropyron-Astragalus* association. The abundance of small stones on the soil surface is characteristic of this unit.

as large or well developed as they were in other associations. *A. spicatum* had a cover of 7 percent, exceeded only in the *Juniperus/Artemisia/Agropyron* association. Cover of *A. tridentata* was 6.7 percent. Stand density of this species was 26 plants per 0.02 acre, and mature plant height averaged 1.26 feet.

*Astragalus lectulus* was quite specific to this association. It had a constancy rating of 100 percent with a cover value of 0.1 percent. The species occurred in two other units, the *Juniperus/Festuca* and *Juniperus/Agropyron* associations, but had constancy ratings of only 60 and 17 percent, respectively, and was not found on the observation plots.

This association was comparatively deficient in perennial herbaceous species. Only 13 different species occurred in sufficient quantities and abundance to provide some basis for characterization. Eight of these, *A. spicatum*, *Poa secunda*, *Koeleria cristata*, *Achillea millefolium*, *Phlox douglasii*, *Astragalus* sp., *Erigeron linearis*, and *Astragalus lectulus*, attained 100-percent constancy. The remaining five, *Agoseris* sp., *Eriophyllum lanatum*, *Stipa thurberiana*, *Sitanion hystrix*, and *Eriogonum umbellatum*, had constancy ratings of 50 percent or less.

The soil occurring with the *Juniperus/Artemisia/Agropyron-Astragalus* association was a Brown loam formed from rhyolitic-andesitic colluvium (series IX). Solum depth was 21 inches. Large stones occupied 50 percent of the profile volume. Below 21 inches, 90 percent of the soil volume was large stones. A discontinuous caliche often occurred at approximately 21 inches below the surface. Very few roots extended below this area.

The heaviest part of the B horizon was a clay. Structure of this clayey layer was strong and blocky with hard, dry consistence but friable when moist. This friability, in addition to solum stoniness, allowed deeper root penetration than might be expected (fig. 29). Available water storage capacity in the 2- to 14-inch soil zone was 1.21 inches, the lowest capacity of any of the zonal soils (table 3). Organic matter and total nitrogen of the A horizon were 1.63 and 0.08 percent, respectively.

The soil surface was covered with an abundance of small stones which provided an aspect of an erosion pavement (fig. 30). This was a natural phenomenon and must not be interpreted as an induced pavement created by accelerated erosion. Most of these small stones were lichen covered, and there was no evidence of soil displacement.

# Discussion

## Vegetation-Soil Relationships

Plant communities and the soils supporting them are functional products of the same large environmental factors (climate, organisms, relief, parent material, and time) (Major 1951; Jenny 1941). Therefore, it should be expected that direct relationships exist between interpreted categories of the two complexes. If this occurred, it would be relatively simple to characterize ecosystems by relating general vegetation and soil characteristics obtained by field surveys.

Some early workers indicated this to be true, although categorical units of soil or vegetation were not identified. Griffiths (1902) claimed that when *Agropyron spicatum* was associated with *Artemisia* spp. in the northern Great Basin, soils were almost invariably stony and fertile. Kearney *et al*. (1914) suggested the possibility of correlating vegetational distribution with soil chemical and physical properties. Graham (1937) recognized that altitudinal zonation of vegetation was due primarily to climatic factors, but the zones were often divisible on the basis of edaphic or physiographic factors.

Only in the past two decades has much work been done to correlate taxonomic vegetation and soil units. A major problem in identifying direct associations between the two complexes is related to the different disciplines under which classification of each has evolved. Most soils in the United States have been classified with an agricultural bias which has resulted in essentially a technical classification (U. S. Bur. Plant Indus., etc. 1951). With the development of a more comprehensive system, all or most of this bias should be eliminated (U. S. Soil Conservation Service 1960). Natural vegetation, on the other hand, has been classified more or less under a natural system even though plant succession has often been ignored and community separations have not been specific enough to delineate natural groupings with relatively homogeneous characteristics.

Spilsbury and Tisdale (1944) found that *Agropyron spicatum* was dominant on practically every soil type they encountered. However, they noted marked differences in density, height, and yield of the species depending on soil depth. Later, Tisdale (1947) described three vegetation zones (*Agropyron-Artemisia*, *Agropyron-Poa*, and *Agropyron-Festuca*) and found them to be correlated with three great soil groups, Brown, Chestnut, and Chernozem. Within each zone, however, he recognized edaphic and biotic communities characterized by changes in species presence and dominance.

Gardner and Retzer (1949) inferred that soil series level interpretations were adequate for classifying wildland soils in most cases. Later, Retzer (1953) pointed out more definitely that

the soil series was the most useful unit for classifying wildlands on the basis of vegetation-soil correlations. Poulton[6], however, using polyclimax concepts to classify climax communities in the northeastern Oregon Columbia Basin, showed that each type of climax was associated with a particular group of soil series. Anderson (1956) showed that certain range "sites" in eastern Oregon were related to definite groups of soil series when zonal soils were involved. Eckert[7], after classifying some climax *Artemisia* types in southeastern Oregon, also found that a climax type was associated with numerous soil series. Dyrness[8] classified climax communities associated with azonal soils in the ponderosa pine zone in southern Oregon. He showed that direct vegetation-soil association occurred at the phase of soil-type level of interpretation if characteristics other than those used for profile descriptions were considered.

These investigations show conflicting opinions concerning the categorical level of soil associated directly with climax plant communities. The results indicate that in addition to differences in the way the two complexes are classified, compensatory environmental factor interactions strongly influence these relationships. This was summarized well by Poulton and Tisdale (1961) who concluded that factor compensation may result in apparently identical plant communities occurring on two or more taxonomic soil units or that different plant communities may occur on the same taxonomic soil unit.

The relationships between the interpretive categories of the vegetational and soil components of the ecosystems delimited in this study are varied. Table 6 illustrates the relation between tentatively classified taxonomic soil units and the plant associations with which they occur.

[6] Poulton, Charles E. Ecology of the non-forested vegetation in Umatilla and Morrow Counties, Oregon. 166 pp. 1955. Ph.D. thesis on file Washington State University.

[7] See footnote 2.

[8] Dyrness, Christian Theodore. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. 217 pp. 1960. Ph.D. thesis on file Oregon State University.

Table 6.—Relation between tentatively classified soils and plant associations in the central Oregon juniper zone

| Series and phase number | Generalized type or phase of type description | Plant association |
|---|---|---|
| Series I | Chestnut loam from rhyolitic-andesitic colluvium on northerly slopes | *Juniperus/Artemisia/Festuca* |
| Series II: shallow, nonstony phase | Shallow, nonstony sandy loam Regosol over gravelly loam alluvium and rhyolitic-andesitic colluvium on northern slopes | *Juniperus/Artemisia/Festuca-Lupinus* |
| Series III | Brown loam from friable tuffaceous material on northwesterly slopes | *Juniperus/Festuca* |
| Series III: very stony phase | Very stony Brown loam from friable tuffaceous material on southeasterly slopes | *Juniperus/Festuca: Purshia* variant |
| Series IV | Weakly developed Brown loam from mixed rhyolitic-andesitic colluvium and aeolian sands on northerly slopes | *Juniperus/Festuca* |
| Series II: moderately deep, extremely stony phase | Moderately deep, extremely stony, sandy loam Regosol over cracked or closely packed basalt on northerly slopes | *Juniperus/Artemisia/Agropyron-Chaenactis* |
| Series V | Strongly developed Brown loam from coarse river- and lake-laid sediments containing basalt fragments on undulating uplands | *Juniperus/Artemisia/Agropyron* |
| Series VI | Strongly developed Brown loam from loess, very fine river sands, and small basalt fragments on undulating uplands | *Juniperus/Artemisia/Agropyron* |
| Series VII | Brown sandy clay loam from a thin layer of rhyolitic-andesitic colluvium over indurated tuffaceous material on northeasterly slopes | *Juniperus/Agropyron* |
| Series VII: shallow phase | Shallow Brown sandy clay loam from a thin layer of rhyolitic-andesitic colluvium over indurated tuffaceous material on northerly slopes | *Juniperus/Agropyron* |
| Series VIII | Brown loam from rhyolitic-andesitic colluvium on southeasterly slopes | *Juniperus/Agropyron: Purshia* variant |
| Series II: deep, nonstony phase | Deep, nonstony, sandy loam Regosol over a buried, loamy, stony B2 horizon on northeasterly slopes | *Juniperus/Artemisia-Purshia* |
| Series II: moderately deep, very stony phase | Moderately deep, very stony, sandy loam Regosol over closely packed and cemented rhyolitic-andesitic colluvium on easterly slopes | *Juniperus/Agropyron-Festuca* |
| Series IX | Brown loam developed from rhyolitic-andesitic colluvium on southwesterly slopes | *Juniperus/Artemisia/Agropyron-Astragalus* |

Two primary assumptions are made upon examination of the data. With azonal soils, soils with immature profile characteristics, the phase of soil series type level of interpretation provides direct correlation with a specific plant association. In this case, four associations are found with specific phases of the same soil series—the *Juniperus/Artemisia/Festuca-Lupinus*, *Juniperus/Artemisia/Agropyron-Chaenactis*, *Juniperus/Artemisia-Purshia*, and *Juniperus/Agropyron-Festuca* associations. Zonal soils, soils having relatively mature profile characteristics, show little direct affinity for a specific plant association, regardless of level of interpretation. For example, the *Juniperus/Festuca* association occurred with two soil series and a phase of one of these series; the *Juniperus/Artemisia/Festuca* association occurred with one soil series.

Azonal soils.—The azonal soils encountered in this study are developing on parent materials of relatively recent origin. They have not reached equilibrium with the current environment and, generally, possess uniform profile characteristics. Therefore, factors genetically unrelated to the soils, including subsoil characteristics, are creating the differences in vegetation.

Phases of the soil-series-type interpretations were based on depth, stoniness, and nature of the underlying material. The deep, nonstony phase of series II, occurring with the *Juniperus/Artemisia-Purshia* association, was separated primarily on depth (45 inches) and nonstoniness. Rooting depth is not mechanically restricted, but the sandy nature of the soil allows for rapid water infiltration and drainage, deep water penetration, and comparatively excessive evaporation from near the surface. Consequently, more precipitation is needed to maintain effective, available water than in finer textured, shallower soil (Lutz *et al.* 1947). Lateral soil moisture drainage from positions above the location of this soil may supply additional water to the subsoil. As a result, this soil favors shrubby species such as *Artemisia tridentata* and *Purshia tridentata*, which characteristically root deeply in addition to maintaining roots in the surface horizons. Available soil moisture in the surface horizons is apparently not maintained long enough to allow a major expression of herbaceous species.

In contrast to the preceding soil, the shallow, nonstony phase of series II supporting the more luxuriant community of the *Juniperus/Artemisia/Festuca-Lupinus* association is shallower (16 inches), overlying a gravelly, loamy material. The internal water relations between the two soils, measured by available soil moisture storage capacity in the 2- to 14-inch soil zone, are nearly the same. However, the proximity of the underlying strata to the surface of this soil provides a better environment by increasing storage of available water at a place where it is more effective. Roots are common in the underlying material of this soil, but very few occur in the same strata of the deeper soil. In addition, the nature of the plant community modifies the environment to make it more effective. The comparatively high cover of perennial herbs reduces water evaporation from the soil surface, which probably results in increased effectiveness of total precipitation.

More subtle changes in soil characteristics as related to their associated vegetations exist between the *Juniperus/Artemisia/Agropyron-Chaenactis* and *Juniperus/Agropyron-Festuca* associations. The soils are nearly identical except for the nature of the underlying material and stoniness of the solum. The soil occurring with the *Juniperus/Artemisia/Agropyron-Chaenactis* association has 50 percent of its volume occupied by large stones, and it overlies cracked or closely packed bedrock which allows some root penetration. The soil occurring with the *Juniperus/Agropyron-Festuca* association has slightly less volume occupied by large stones (35 percent), but it overlies large stones which have been cemented with carbonate or silicate precipitates. The cementation prevents root penetration (Veihmeyer and Hendrickson 1948). Depth to the underlying material is the same in both soils. Available moisture storage in the 2- to 14-inch soil zone is only slightly

different, 0.87 inch in the *Juniperus / Artemisia / Agropyron- Chaenactis* association and 0.97 inch in the *Juniperus / Agropyron.-Festuca* association. Therefore, the penetrability of the underlying material to roots is probably a primary factor associated with the vegetational differences. *Juniperus occidentalis* and *Artemisia tridentata* are more strongly expressed in the *Juniperus / Artemisia / Agropyron -Chaenactis* association, where they can root deeper and not be subjected to competitive stresses as intense as caused by the cemented stratum occurring in the soil supporting the *Juniperus / Agropyron-Festuca* association.

In summary, direct vegetation-soil correlation with azonal soils can be shown at the phase of soil-type level of interpretation if phase separation considers the nature of the underlying material as well as solum characteristics. If solum characteristics only are considered, direct correlation becomes nonexistent and differences in plant associations are harder to explain.

Zonal soils.—The nonspecific vegetation-soil correlation of those associations occurring with zonal soils indicates that environmental factor interactions and compensations strongly influence the occurrence and dispersion of the plant communities. Relationships among the following factors as they affect the soil moisture regime and root growth appear to be the most important:

1. Texture, structure, and thickness of the densest part of the B horizon
2. Stones on and in the soil
3. Solum depth
4. Nature of the underlying material
5. Intensity and duration of insolation as indicated by slope aspect

This assumption is illustrated in table 3, which shows a discrepancy between available soil moisture storage capacity in the 2- to 14-inch soil zone and the relative mesic condition of the units. The soil of the most mesic unit does not have the most moisture storage capacity as indexed in this manner; the soil of the most xeric unit does not have the least capacity. However, if quantitative determinations of "effective" moisture storage could be made, a sequential arrangement would probably occur.

The comparative mesic condition of the *Juniperus/Artemisia/Festuca* association occurring with series I is improved primarily by solum stoniness and depth and the topographic position of the unit. The fact that roots are well distributed into the parent material is evidence of the soil effectiveness, even though the densest portion of the B horizon has a clay texture and strong, blocky structure.

The presence of clayskins on individual soil peds in this horizon is indicative of clay colloids leaching from surface horizons. These characteristics indicate that a claypan could have formed but the high stone content (50 percent) has prevented this from occurring. At the same time, the stones have provided for more "porous" soil conditions (Lutz and Chandler 1946), allowing good water percolation and reducing mechanical impedence to root growth. The clayey texture of all the subsoil allows for maximum water storage. The northerly aspect provides for minimum insolation (Geiger 1957) and reduced evaporation. As a result, the precipitation falling on this soil is more effective in adding to and supplying effective, available soil moisture.

The *Juniperus / Festuca* association is supported by strikingly different soils representing two series. The efficiency of the two soils is equalized by compensating effects of texture and structure of the densest part of the B horizon, solum depth, and the nature of the underlying material. The shallow, clayey textured, relatively strong structured subsoil of series III reduces the effective soil moisture and impedes root growth as compared with the deeper, loamy, less well-developed subsoil of series IV. However, the same amount of precipitation is effective longer in the subsoil of series III because of its texture and structure characteristics, and some moisture is probably drawn from the underlying friable-and-porous-when-wet tuffa-

ceous material. These factors compensate for the shallowness of the soil to supply the same amount of effective soil moisture as series IV. These soils, when compared with series I occurring with the *Juniperus /Artemisia/Festuca* association, are more droughty because of the shallow, nonstony characteristics of series III and the coarser texture of series IV.

The increase in cover of *Purshia tridentata* and reduction in cover of *Festuca idahoensis* in the *Purshia* variant of the *Juniperus/ Festuca* associations is related to stoniness of the stony phase of series III and slope aspect. The stones (50 percent by volume) modify the clayey texture and strong structure of the subsoil (Bradfield and Jamison 1939) to provide less resistance to root penetration of *Purshia tridentata*. Also, the easterly aspect favors the development of this species. However, the increased insolation with a corresponding rise in soil surface temperature apparently approaches lethal conditions for *Festuca idahoensis*. Nevertheless, the stones on and in the soil provide slower soil heating and less heat loss (Lutz and Chandler 1946), compensating partially for the increased insolation and the northerly slope aspect of the normal position of the association. The resultant effect is the maintenance of dominance of *Festuca idahoensis* in the herbaceous layer, although in a reduced state, and no significant change in cover of species other than *Purshia tridentata*.

Series V and VI, which occurred with the *Juniperus /Artemisia /Agropyron* association, are quite similar morphologically to series I, which occurred with the *Juniperus /Artemisia / Festuca* association. However, the solums of series V and VI are rock free, and a claypan has developed near the soil surface. As a result, the biological effectiveness of these soils is reduced (Bonner and Galston 1952, Carlson 1925, Kramer 1945), even though available soil moisture storage capacity exceeds that of all other soils encountered in this study. Root growth is restricted by the claypan (Veihmeyer and Hendrickson 1948) and, consequently, the effectiveness of the available soil moisture is reduced. In addition, the nonstoniness of the soils and the level aspect reduce moisture effectiveness through water vaporization in the soil and evaporation from the soil created by longer, more intense insolation.

Although two taxonomic soil units occur with the *Juniperus /Artemisia /Agropyron* association, their apparent biological effectiveness is the same. The variation in position and thickness of the claypan and the nature of the underlying material of the two soils compensate to provide equivalent soil environments. Few roots are present in the relatively deep, thick clayey zone of series V, and no roots grow through it. In series VI, few roots also occur in the shallower, thinner, slightly coarser clayey zone. However, some roots penetrate this soil layer and grow into the looser underlying material to take advantage of the growth-supporting potential in this soil zone. As a result, the plant growth influences of the deeper, thicker, denser claypan of series V are equalized by the shallower, thinner, coarser claypan of series VI. Consequently, the combined characteristic of the plant communities on both soils represent the vegetational component of the same ecosystem.

The relative abundance of comparatively xeric species, particularly *Agropyron spicatum*, in the *Juniperus /Agropyron* association is peculiar since the easterly aspect would normally indicate comparatively good moisture conditions. However, solum and soil surface stoniness (35 and 18 percent, respectively) and the texture and nature of the underlying material of series VII occurring with this association compensate the topographic position of the unit.

The stones reduce the rate of heating as well as heat loss which favors relatively mesic conditions. However, the stones on and in this soil reduce its effective volume. Also, the soil separates of the sandy clay loam and clayey surface and subsoils are apparently of such size and distribution to allow close packing. This results in a reduction of porosity and a corresponding reduction of available moisture storage

capacity. With the exception of the zonal soil occurring with the *Juniperus/Artemisia/Agropyron-Astragalus* association, moisture storage is less in this soil than in any of the other zonal soils. In addition, the indurate tuffaceous material restricting root growth adds to the droughty condition of the entity. The direct and indirect effects of these characteristics overcome the slope aspect effects and result in a xeric community in an area which might be mistakenly classified comparatively mesic.

The loam surface horizon and clay loam subsoils of series VIII, penetrability of the substrattum, and the more southerly aspect account mainly for the increase of *Purshia tridentata* in the *Purshia* variant of the *Juniperus/Agropyron* association. The penetrable subtratum allows for relatively deep rooting of *P. tridentata*, a site requirement necessary for the species. Also, the more southerly aspect favors its development as a result of factor interactions similar to those in the *Purshia* variant of the *Juniperus/Festuca* association. The finer texture of this soil, as compared with the series VII occurring with the association, makes available soil moisture more effective and compensates for any increase in intensity and duration of insolation from a change in slope aspect. Consequently, the vegetational component of the ecosystem, except *P. tridentata*, is not materially changed.

The comparative xeric condition of the *Juniperus/Artemisia/Agropyron-Astragalus* association is primarily the result of the southerly aspect. This topographic position allows for maximum intensity and duration of insolation (Geiger 1957) with consequent maximum microclimatic temperatures during the growing season. However, the stone content of the solum (50 percent) and the rubbly characteristic of the soil surface modify the insolation effects by reducing the rate of heating as well as the possible maximum temperature of the effective soil. The stones also provide better conditions for water penetration and root growth into the clayey, strongly structured subsoils and reduce evaporation. As a result, the available soil moisture is more effective than it would be if stones were absent. In spite of these conditions, however, the insolation effects are strong enough to create the relative xeric condition. This is shown particularly in the paucity of perennial species and the extremely low cover when the plant layer dominants are not considered.

In summary, direct vegetation-soil correlation of ecosystem vegetational components associated with zonal soils cannot be made at a single categorical level of soil interpretation based on current soil classification procedures. Zonal soils, because of their relative maturity, invoke subtle changes in effective environmental conditions, which may or may not create significant vegetational changes. Therefore, factors not readily identified in the field or whose compensatory or interacting influences cannot be quantitatively measured must be considered when an ecosystem is characterized or differences among ecosystems are rationalized.

Texture, structure, and thickness relationships of the densest part of the B horizon, stones on and in the soil, solum depth, nature of the underlying material, and insolation provide some striking correlations and differences within and among the ecosystems and their plant communities on zonal soils in the central Oregon juniper zone.

## Ecological Status of the Central Oregon Juniper Zone

Climax is a concept familiar to everyone dealing with classification of natural vegetation. Numerous definitions of climax exist (Braun-Blanquet 1932, Weaver and Clements 1938, Odum 1953, Oosting 1956), and they all connote a terminating and dynamically stable plant community determined and maintained by climate. It remains for the worker to interpolate time lapses involved, space relationships, whether the inferred climate is regional or local, physical or bio, or combinations of these, and the degree of heterogeneity characteristic of the equilibrium community.

Whittaker (1953) maintains that no completely rigorous definition of climax exists and that perhaps none need be developed. However, if vegetation is to be used for something other than aesthetic purposes, it must be classified by a system that recognizes the existing natural plant community as being climax and does not attempt to predict what it might be in the future. Selander's (1950) concept of climax and its associated community—a community representing a time phase of great stability in which successional causes cannot be observed and the future cannot be predicted—provides a workable and organized principle. Even though successional causes can be observed, such as fire indicated by charred stumps or logs, if there is no evidence of replacement or no possibility to predict future succession other than that occasioned by community dynamism, the concept remains valid. This concept of climax is the basis of the polyclimax theory which contends that many climaxes exist which are controlled by one or a few environmental factors and are not oriented to a single modal situation.

On this basis, the area in central Oregon, where *Juniperus occidentalis* is a component of relatively undisturbed vegetation, represents a natural unit of vegetation, even though some workers have doubted the existence of the pinyon-juniper zone in other parts of the Western United States as representing climax conditions. Emerson (1932) concluded, from results of studies using limited soil investigations and species lists, that the occurrence of the pinyon-juniper zone in northern New Mexico was associated with areas not occupied by "closed" stands of herbaceous vegetation and was not a true vegetational entity. He also stated that soil characteristics were incidental influences in the way they controlled growth of grasses. These conclusions were similar to those of Cottle (1931) who stated that xeric grasses dominated the vegetation of southwestern Texas and woody plants occurred only in places where rocks or other factors prevented full expression of the grasslands. Emerson (1932) did show that available soil moisture was greater in areas occupied by trees.

Both Emerson (1932) and Cottle (1931) contradicted themselves in these studies. They showed that pinyon pine and juniper, in their study areas, grew where other vegetation could not. Also, they stated that available soil moisture was greater in the pinyon-juniper areas than in associated desert grasslands. These facts strongly indicate the presence of an environment with conditions favorable for the development of a natural vegetational unit.

Woodbury (1947) concluded the pinyon-juniper zone is a natural entity after studying the distribution of "pigmy" conifers (*Juniperus osteosperma*, *J. monosperma*, *J. scopulorum*, *Pinus edulis*, and *P. monophylla*) in Utah and northeastern Arizona. He showed that these species were best adapted to ridges, canyons, or rough slopes with coarse, rocky, or shallow soils. He also showed that the upper and lower limits of these species were set by soil moisture excesses or deficiencies. These excesses or deficiencies, however, are not controlled by climatic factors alone; they interact with the absorptive, storage, and water-supplying powers of the soil to influence effective soil moisture.

Eckert (1957), after characterizing some *Artemisia* types in central Oregon, showed a lower

unit of effective soil moisture below which *Juniperus occidentalis* did not exist although other environmental factors were similar. In this area, he concluded that the species made its maximum growth on rocky outcrops, steep slopes, or intermittent drainageways where the water-supplying power of the soil was slightly greater than the maximum requirement of climax *Artemisia tridentata* or *A. arbuscula* communities.

These conclusions of Woodbury (1947) and Eckert (1957), as well as the results of other studies (Merkle 1952, Rasmussen 1941, Woodbury 1933, Woodin and Lindsey 1954), support the hypothesis that natural plant communities characterized partly by juniper and/or pinyon pine exist and that the prevailing climate is suitable for the perpetuation of these communities. The present study strengthens this conclusion by showing that *Juniperus occidentalis* is a dominant and characteristic species of specific plant associations unaffected by influences other than those occurring naturally.

Recognizing that the central Oregon juniper zone is a natural vegetational entity and that there are specific taxonomic vegetation-soil units within the area has provided a realistic base for management. The current vegetational potentials of these units are defined in terms of kinds and amounts of specific plant species and the relationships between soils and vegetation of the units. Also, if characteristic vegetational components are missing, the ecosystems can still be identified for management purposes on the basis of soil and topographic characteristics. For example, a range manager may have a grazing unit composed mostly of the *Juniperus/Artemisia/Festuca* association where past grazing has deteriorated the desirable cattle forage. Since he knows that the vegetational potentials of the association are approximately 11- and 5-percent cover of *Festuca idahoensis* and *Agropyron spicatum*, respectively, his management will be adjusted accordingly. He will not be satisfied with only 2- and 3-percent cover of these species as demonstrated in the *Juniperus/Agropyron-Festuca* association.

Following polyclimax terminology, the *Juniperus/Artemisia/Agropyron* association is considered the climatic climax of the zone. The association occurs on undulating topography and loamy soils that are moderately drained. The validity of this assumption may be questioned because of the paucity of *Juniperus occidentalis* and the abundance of *Agropyron spicatum* and *Artemisia tridentata*. The energy relationships within and among species were not determined in this study. Consequently, the point cannot be isolated where the influence of a species within any of the associations ceases or becomes insignificant. It is certain, however, that *J. occidentalis* has an influence on the energy relationships within the *Juniperus/Artemisia/Agropyron* association. The species provides shade to modify the microclimate of the entity and removes water and nutrients from the soil that would otherwise be available to other species.

The remaining associations described in this study are considered topoedaphic climaxes. Factors related to the topography and soils of these units appear to be major controlling influences on the distribution of the vegetation. These factors and their relationships within and among the units were discussed in the preceding section.

The vegetation of the study area could have been classified with the continuum concept (Curtis and McIntosh 1951, Whittaker 1951) if single species were considered independently. A family of distribution curves, based on foliage cover, would show that each species has its own distribution center away from which it declines gradually or rapidly as it approaches the margin of its ecological amplitude. This family of curves would also show overlapping ranges among species. For example, *Festuca idahoensis* varies from 0.4-percent cover in the *Juniperus/Artemisia/Agropyron* association to approximately 11-percent cover in the *Juniperus/Artemisia/Festuca* and the *Juniperus/Festuca* associations. *Agropyron spicatum* varies from 0.9-percent cover in the *Juniperus/Artemisia-Purshia* association

to approximately 9-percent cover in the *Juniperus/Artemisia/Agropyron* association. The entire range of cover values of *A. spicatum* among the associations is contained within the cover range of *F. idahoensis*. This substantiates the fact that species groupings very rarely are specific to a single environment and that very rarely does a specific environment completely exclude a species (Selleck 1960, Curtis and McIntosh 1951). Arranging the species into the resulting pattern of complex curves would illustrate the diversity of vegetation but would have little practical value from the land management point of view.

The plant communities could also have been classified with the monoclimax philosophy proposed by Clements (1916). He postulated that climax developed through a certain successional pattern to the "highest type" which is synonymous with a "formation," a unit of vegetation determined and controlled by regional climate. Areas within the formation not conforming to the climax "type" were designated "disclimax," "preclimax," or "postclimax" with reference to vegetation on disturbed sites, dry sites, or moist sites.

Under this system of classification, the *Juniperus/Artemisia/Festuca, Juniperus/Artemisia/Festuca-Lupinus, Juniperus/Festuca,* and *Juniperus/Artemisia/Agropyron-Chaenactis* associations would be considered postclimaxes and the *Juniperus/Agropyron, Juniperus/Artemisia-Purshia, Juniperus/Agropyron-Festuca*, and *Juniperus/Artemisia/Agropyron-Astragalus* associations as "preclimaxes" of the *Juniperus/Artemisia/Agropyron* association, the climatic climax of the zone. From the standpoint of grazing, this kind of classification infers either something better for grazing (postclimax) or something worse (preclimax). Confronted with such a classification, the land manager would have little basis for management since he would be dealing with intangible kinds of units. Cain (1947) aptly expressed this view when he concluded that true climax develops only on medium sites and that linking all stable communities to the climax is highly hypothetical and serves no useful purpose.

In summary, the present study confirms the concepts of Tansley (1935), Billings (1952), Daubenmire (1952), Selander (1950), and Selleck (1960) that the whole of vegetation represents a complex of ecosystems which are natural units of the landscape. Each ecosystem contains a vegetational component which can be classified as an entity easily recognized and adapted to land management.

# Some Practical Applications

The best current use of nonarable lands in the central Oregon juniper zone is forage production for grazing animals. This study has demonstrated that discrete landscape units, ecosystems, exist in the area and that each has its own biological potential. Consequently, each unit also has specific management requirements. Recognition of these facts by the land manager is essential to assure optimum and sustained forage production for the grazing animals.

## Classification and Inventory

A preliminary phase of any range management program involves mapping to show, among other things, the location and distribution of vegetation types. The mapping job is often done in accordance with instructions outlined by the Inter-Agency Range Survey Committee (U. S. Department of Agriculture 1937). The map units as defined by this committee are the vegetation types and are based on the current aspect of vegetation without regard to the ecological status or the recognition of specific units within these types that have specific management characteristics. Subsequent management is then based on the type as a whole. Such faulty vegetation classification places plant communities with different productive potentials and successional patterns in the same category. The resultant effect is chaotic, because a land manager does not know his goals with certainty and cannot correctly interpret the impact of management on the resource.

For example, a typical range survey would probably consider all the described ecosystems as a single unit. Subsequent cattle range management would be based on averages for all ecosystems, showing, for example, the average cover of *Festuca idahoensis* (4.5 percent) and *Agropyron spicatum* (4.2 percent) as the preferred cattle forages. With reference to the first species, stocking rates would be reduced in six out of nine cases or maintained or increased in three out of nine cases, depending on the location of the "key" management area, to fulfill the objective of sustained optimum production of forage. For *Agropyron spicatum*, stocking rates would be reduced in five or maintained or increased in four out of nine cases. In all cases, however, such management decisions are completely unrealistic because of the different productive potentials among the ecosystems.

It is recognized that defined ecosystems very often are not of sufficient areal extent in any one location to constitute a mapping unit or a management unit. The important factor is to recognize, by observation of differences in vege-

tational, soil, topographic, or other characteristics, that such entities exist and must be considered in classifying and managing rangelands. Emphasis by others on this point (Costello 1957, Ellison 1949, Parker 1954) has stressed the need for placing range classification on a sound natural basis.

The apparent difficulty involved in mapping, inventory, and subsequent planning is overcome simply by including each ecosystem as a part of a mapping complex and recognizing the basic characteristics of each as contributory, but independent, integers of the complex. These procedures are being used by some agencies and private operators managing native vegetation by incorporating results of similar studies (Dyrness[9], Eckert[10], Poulton[11]). The question "How can management of an area be effective if that area consists of numerous, independent units?" can rightfully be asked. The individual manager or user must decide if current or predicted economics warrant individual management of each ecosystem or if some units will be sacrificed by basing management on others.

## Range Condition and Trend

Another type of practical application concerns evaluation of range condition and trend based on guides or standards developed for each vegetation-soil unit. Range condition is range health, the relative successional position of a site with regard to the inherent potential of the site. Range trend is the direction of change in condition and shows whether a range site is holding its own or becoming more or less productive as compared with the site potential.

Range condition classification should strongly consider the kind of animal that is or will be using a particular area. For example, all the associations described are ecologically in excellent condition. However, when the grazing animal is considered, condition classifications among associations will vary. The vegetation of the *Juniperus/Artemisia/Festuca* association would be considered excellent for cattle because of the abundance of desirable cattle forages. On the other hand, this same unit would rank low for deer because of the relative paucity of deer forage, normally shrubs and forbs. With reference to the *Juniperus/Artemisia Purshia* association, the rating of this area would be relatively high for deer but low for cattle because of the comparative abundance of deer forages and absence of cattle forages.

Compared with other units, the *Purshia* variant of the *Juniperus/Agropyron* association would rank high in condition for deer but slightly lower for cattle. Stable soil is assumed in all these hypothetical condition ratings. It would behoove a range manager, then, to rate range condition to the animal as well as to the area rather than the latter alone. This would implement range classification and use by defining the most practicable grazing use of specific associations.

Range trend must also consider the kind of animal using an area. For example, continued heavy cattle use in the *Juniperus/Artemisia-Purshia* association would reduce and perhaps eventually eliminate the grasses and some forbs. The resultant vacuum in the plant community would probably be filled by an increase in density and cover of shrubs, particularly *Purshia tridentata*, a highly desirable deer forage. Thus, at a given time, an upward trend could be indicated for deer range and a downward trend for cow range.

The validity of condition and trend classification is determined largely by the way the vegetation is classified initially. If, for example, the whole area was classified as a single entity, condition and trend determinations would be based partly on the average foliage cover of *Festuca idahoensis* (4.5 percent). A sampling location to determine range condition might be

[9] See footnote 8.
[10] See footnote 2.
[11] See footnote 6.

located in the *Juniperus / Artemisia / Agropyron* association where, under existing ecological conditions, foliage cover of this species is only 0.4 percent and individual plants occur only in the deep shade of shrubs and trees. Subsequent condition ratings would always be extremely low, based on the assumption that the sampled area should have at least 4.5-percent foliage cover of *F. idahoensis*. As a result, the grazing load would be reduced in an attempt to allow for an increase of the species, something that would be unlikely to happen within reasonable time. In this case, forage would be wasted that could otherwise be utilized if the initial vegetation classification provided for separation of specific associations.

## Range Rehabilitation

Future range rehabilitation programs for either game or livestock can be enhanced by the results of this study. If a decision were made to improve game forage conditions by seeding *Purshia tridentata*, those associations located on aspects receiving moderate insolation and having soils which allow deep root penetration with little mechanical impedence would be selected initially to give the best results. With reference to cattle range improvement, drought-tolerant, shallow-rooting species would be selected for sites having soils similar to those found with the *Juniperus / Artemisia / Agropyron* association. The claypan close to the surface of these soils would inhibit growth of deep-rooting species unless it is mechanically altered by cultural practices such as deep plowing. On the other hand, deeper rooting species which can take advantage of deeper soil moisture storage would be used in sites with soils similar to those found with *Juniperus /Artemisia / Festuca* association. The clayey but stony subsoils and northerly aspect of this unit provide more biologically effective moisture than is found in the soils occurring with the *Juniperus / Artemisia / Agropyron* association.

# Summary


1. The pinyon-juniper zone in Oregon, characterized in the tree overstory by *Juniperus occidentalis* and referred to as the juniper zone, is subdivided into three physiographic units. These are based on soil parent materials and include: (1) aeolian sands in central Oregon, primarily Deschutes, Crook, and Jefferson Counties; (2) residual igneous material located in north-central, south-central, and southeastern Oregon; and (3) old sediments located in the upper regions of the John Day and Crooked Rivers.

2. In the central Oregon juniper zone, the plant association and soils of nine relatively undisturbed ecosystems and variants of two are defined and characterized in accordance with polyclimax concepts. Simultaneous analysis and interpretation of selected vegetational, soil, and topographic characteristics provided classificatory criteria for each unit. Vegetational characteristics included foliage cover, basal area, heights and density of shrubby and suffrutescent species, and constancy. Soil characteristics used were (1) complete morphological soil descriptions including estimates of bare soil surface, amounts of stone on and in the soil, available soil moisture storage capacity in the 2- to 14-inch soil zone, organic matter, and total nitrogen in the A horizon and (2) textural analyses of the A and the AC horizons in azonal soils and the A and B horizons in zonal soils. The only topographic characteristic useful for characterization purposes was slope aspect. Elevation, slope position, and slope steepness appeared to have little influence on species or community distribution.

3. A taxonomic key to the associations was developed from vegetational, soil, and topographic characteristics easily recognized in the field. Areas where vegetation was disturbed by grazing or other causes were easily classified as to specific associations with this key.

4. The associations described are in climax condition. Successional causes could not be determined and future changes could not be predicted.

5. Direct correlations existed between interpreted phases of azonal soil types and four of the associations. This occurred when soil unit interpretation included the nature of the underlying material and the effects of this material on plant growth.

6. Direct correlations did not always exist between interpreted categories of zonal soils and specific associations. Three of the five associations with zonal soils occurred with more than one interpretive soil unit. A single soil series was directly associated with the other two plant associations.

7. With those associations occurring with zonal soils, cause-and-effect relationships between vegetation and soils were refined by consideration of interactions and compensations among the following factors: (1) texture, structure, and thickness of the densest part of the B horizon; (2) stones on and in the soil; (3) solum depth; (4) nature of the underlying material; and (5) intensity and duration of insolation as indicated by slope aspect.

8. Practical applications of the findings to range and wildlife habitat management and additional research are suggested.

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# Appendix 1.

## Scientific Names, Authors, and Common Names of Species Mentioned in the Text[12]

[12] Nomenclature and authorities for grasses from Hitchcock (1950), for trees from Little (1953), and for shrubs and forbs from Abrams (1940-60). Kelsey and Dayton (1942) is the primary source for common names.

| SCIENTIFIC NAME AND AUTHORITY | COMMON NAME |
|---|---|
| *Achillea millefolium* L. | common yarrow |
| *Agoseris* Raf. | agoseris |
| *Agropyron spicatum* (Pursh) Scribn. & Smith | bearded bluebunch wheatgrass |
| *Artemisia* L. | sagebrush |
| *Artemisia arbuscula* Nutt. | low sagebrush |
| *Artemisia tridentata* Nutt. | big sagebrush |
| *Astragalus* (Tourn.) L. | milkvetch |
| *Astragalus lectulus* S. Wats. | purple woolly-pod |
| *Bromus tectorum* L. | cheatgrass brome |
| *Carex filifolia* Nutt. | threadleaf sedge |
| *Chaenactis douglasii* (Hook.) Hook. & Arn. | Douglas chaenactis |
| *Chrysothamnus nauseosus* (Pall.) Britt. | rubber rabbitbrush |
| *Chrysothamnus viscidiflorus* (Hook.) Nutt. | Douglas rabbitbrush |
| *Collinsia parviflora* Dougl. | littleflower collinsia |
| *Collomia grandiflora* Dougl. | collomia |
| *Cryptantha ambigua* (A. Gray) Greene | cryptantha |
| *Erigeron filifolius* Nutt. | threadleaf fleabane |
| *Erigeron linearis* (Hook.) Piper | lineleaf fleabane |
| *Eriogonum* Michx. | eriogonum |
| *Eriogonum baileyi* S. Wats. | Bailey's eriogonum |
| *Eriogonum microthecum* Nutt. | slenderbrush eriogonum |
| *Eriogonum ochrocephalum* S. Wats. | woolly eriogonum |
| *Eriogonum sphaerocephalum* Dougl. | rock eriogonum |
| *Eriogonum umbellatum* Torr. | sulfur eriogonum |
| *Eriophyllum lanatum* (Pursh) Forbes | woolly eriophyllum |
| *Festuca idahoensis* Elmer | Idaho fescue |
| *Festuca octoflora* Walt. | sixweeks fescue |
| *Gayophytum lasiospermum* Greene | groundsmoke |
| *Grayia spinosa* (Hook.) Moq. | spiny hopsage |
| *Grossularia velutina* (Greene) Cov. & Britt. | desert gooseberry |

| | |
|---|---|
| *Juniperus monosperma* (Engelm.) Sarg. | one-seed juniper |
| *Juniperus occidentalis* Hook. | western juniper |
| *Juniperus osteosperma* (Torr.) Little | Utah juniper |
| *Juniperus scopulorum* Sarg. | Rocky Mountain juniper |
| *Koeleria cristata* (L.) Pers. | prairie junegrass |
| *Leptodactylon pungens* (Tor.) Rydb. | granite gilia |
| *Linanthus harknessii* (Curran) Greene | Harkness gilia |
| *Lomatium triternatum* (Pursh) Coult. & Rose | Nineleaf lomatium |
| *Lupinus* L. | lupine |
| *Mentzelia albicaulis* Dougl. | whitestem mentzelia |
| *Montia perfoliata* (Donn) Howell | miner's lettuce |
| *Penstemon cinereus* Piper | ashen penstemon |
| *Phlox douglasii* Hook. | Douglas phlox |
| *Pinus* L. | pine |
| *Pinus edulis* Engelm. | pinyon pine |
| *Pinus monophylla* Torr. & Frem. | singleleaf pinyon |
| *Pinus ponderosa* Laws. | ponderosa pine |
| *Poa secunda* Presl. | Sandberg bluegrass |
| *Purshia tridentata* (Pursh) DC. | antelope bitterbrush |
| *Ribes cereum* Dougl. | wax currant |
| *Sitanion hystrix* (Nutt.) J. G. Smith | bottlebrush squirreltail |
| *Stipa comata* Trin. & Rupr. | needle-and-thread |
| *Stipa thurberiana* Piper | Thurber needlegrass |
| *Tetradymia canescens* DC. | gray horsebrush |

# Appendix 2.

## Tentative Descriptions of Soil Series and Phases with Related Associations

SERIES I: Chestnut loam from rhyolitic-andesitic colluvium on northerly slopes.
Related association: *Juniperus / Artemisia / Festuca*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-3 | Very dark-brown (10YR 2/2 moist), dark-gray (10YR 4/1 dry) loam; moderate, coarse platy breaking to single grain; loose, very friable, very slightly sticky, very slightly plastic; pH 6.0; common roots; boundary abrupt, smooth. |
| A12 | 3-10 | Very dark-brown (10YR 2/2 moist), dark-brown (10YR 3/3 dry) silt loam; weak, medium, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 6.5; abundant roots; boundary clear, smooth. |
| B1 | 10-15 | Dark-brown (10YR 3/3 moist), dark yellowish-brown (10YR 3/4 dry) silty clay loam; weak, fine, angular blocky; hard, firm, slightly sticky, slightly plastic; pH 7.0; common to abundant roots; boundary clear, wavy. |
| B21 | 15-20 | Dark yellowish-brown (10YR 3/4 moist), dark-brown (10YR 4/3 dry) clay loam; moderate, medium, angular blocky; hard, firm, sticky, plastic; pH 7.0; few to common roots; boundary clear, wavy. |
| B22 | 20-30 | Dark yellowish-brown (10YR 4/4 moist), dark yellowish-brown (10YR 4/4 dry) clay; strong, medium, angular blocky; very hard, firm, sticky, plastic; pH 8.0; few to common roots; boundary abrupt, smooth; common clayskins on the ped surfaces. |
| C(Dr) | 30+ | Dark yellowish-brown (10YR 4/4 moist), yellowish-brown (10YR 5/4 dry) clay loam; weak, fine, angular blocky; firm, hard, slightly sticky, slightly plastic; pH 8.0; few roots. Soil mainly thin coatings around large rhyolitic and andesitic stones. |

Large rhyolitic or andesitic stones compose 45 to 50 percent of the solum volume. Calcareous deposits are common on ped surfaces and stones in the lower B and C horizons. Pumice is distributed throughout the profile. The surface horizon is strongly vesicular.

SERIES II: Sandy loam Regosol on north and east slopes in the Brown zone and developed from pumiceous sands.
Related associations: *Juniperus / Artemisia / Festuca-Lupinus*
*Juniperus / Artemisia / Agropyron-Chaenactis*
*Juniperus / Artemisia -Purshia*
*Juniperus / Agropyron-Festuca*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-3 | Dark-brown (10YR 3/3 moist), gray-brown (10YR 5/2 dry) sandy loam; medium, thick platy breaking to single grain; loose, nonsticky, nonplastic; pH 6.0; common roots; boundary abrupt, smooth. |
| A12 | 3-7 | Dark-brown (10YR 3/3 moist), brown (10YR 5/3 dry) sandy loam; single grain; loose, nonsticky, nonplastic; pH 6.5; abundant roots; boundary clear, smooth. |

| | | |
|---|---|---|
| AC | 7-14 | Dark yellowish-brown (10YR 3/4 moist), brown (10YR 5/3 dry) sandy loam; single grain; soft, loose, nonsticky, nonplastic; pH 7.0; abundant roots; boundary clear, smooth. |
| C | 14-22 | Dark yellowish-brown (10YR 3/4 moist), brown (10YR 4/3 dry) sandy loam; single grain; loose, nonsticky, nonplastic; pH 7.5; common to abundant roots; boundary clear, wavy. |

The soil contains approximately 30 percent pumice by volume. The surface horizon is strongly vesicular. The soil overlies unrelated material.

Four phases of this series type are recognized. Phase separation was based on depth to the underlying material, characteristics of the underlying material, and solum stoniness. Each phase occurs with a separate association.

Shallow, nonstony phase: Shallow (16 inches), nonstony over gravelly, loamy, alluvium and rhyolitic and andesitic stones; 50 percent of the underlying material is large stones; roots are common in the underlying material; occurs on north to northeast slopes.

Related association: *Juniperus/Artemisia/-Festuca-Lupinus*

Moderately deep, extremely stony phase: Moderately deep (26 inches), extremely stony over cracked or closely packed basalt; the solum contains approximately 50 percent large stones; 90 percent of the underlying material is large stones; few roots penetrate the cracks of the underlying material; occurs on northwest to northeast slopes.

Related association: *Juniperus/Artemisia/Agropyron-Chaenactis*

Deep, nonstony phase: Deep (45 inches), nonstony over a loamy, B2 horizon; 50 percent of the underlying material is small stones; very few roots extend into the underlying material; occurs on north to northeast slopes.

Related association: *Juniperus/Artemisia-Purshia*

Moderately deep, very stony phase: Moderately deep (23 inches), very stony over large, closely packed rhyolitic and andesitic stones cemented with carbonates and/or silicates; the solum contains approximately 35 percent large stones; roots do not penetrate the cemented material; occurs on east slopes.

Related association: *Juniperus/Agropyron-Festuca*

SERIES III: Brown loam from tuffaceous material on northwesterly slopes.

Related association: *Juniperus/Festuca*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-2 | Very dark-gray-brown (10YR 3/2 moist), gray-brown (10YR 5/2 dry) loam; moderate, medium, platy; soft, loose, slightly sticky, slightly plastic; pH 6.0; abundant roots; boundary abrupt, smooth. |
| A12 | 2-6 | Very dark-gray-brown (10YR 3/2 moist), dark-gray-brown (10YR 4/2 dry) loam, moderate, medium, crumb; soft, very friable, slightly sticky, slightly plastic; pH 6.5; abundant roots; boundary abrupt and smooth. |
| B1 | 6-9 | Dark yellowish-brown (10YR 4/4 moist), dark-brown (10YR 4/3 dry) clay loam; moderate, fine, angular blocky; hard, friable, slightly sticky, slightly plastic; pH 6.5; common roots; boundary clear, smooth. |

| | | |
|---|---|---|
| B2 | 9-13 | Dark-brown and dark yellowish-brown (10YR 3/4, 4/4 moist), dark-brown (10YR 4/3 dry) clay; moderate, medium prismatic breaking to strong, medium, angular blocky; very hard, very firm, sticky, plastic; pH 7.0; roots common; boundary clear, wavy. |
| B3 | 13-18 | Brown (10YR 4/3 moist), yellowish-brown (10YR 5/4 dry) clay loam; moderate, medium, angular, blocky; hard, friable, slightly sticky, slightly plastic; pH 7.5; few to common roots; boundary clear, wavy. |
| C(Dr) | 18+ | Tuffaceous material very hard when dry becoming friable when moist. Roots are common, apparently penetrating when the material is wet. |

The modal type of this series is relatively stone free; 5 percent of profile volume is occupied by stones. Pumice is distributed throughout the profile. This soil is normally on north- to northwest-facing slopes. The surface horizon is strongly vesicular.

Very stony phase: Very stony Brown loam from friable, tuffaceous material; the solum contains approximately 50 percent large rhyolitic and andesitic stones unrelated to the solum; occurs on southeasterly slopes; horizon number, sequence, and characteristics are the same as the series type.

Related association: *Juniperus/Festuca-Purshia* variant

SERIES IV: Weakly developed Brown loam from mixed rhyolitic andesitic colluvium and aeolian sands on northerly slopes.

Related association: *Juniperus/Festuca*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A1 | 0-9 | Very dark-gray-brown (10YR 3/2 moist), dark-gray-brown (10YR 4/2 dry) loam; moderate, medium, granular; soft, loose, slightly sticky, slightly plastic; pH 6.0; abundant roots, boundary clear, smooth. |
| B1 | 9-15 | Dark-brown (10YR 3/3 moist), dark-brown (10YR 4/3 dry) loam; weak medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary clear, wavy. |
| B2 | 15-28 | Dark-brown (10YR 3/3 moist), yellowish-brown (10YR 5/6 dry) silt loam; weak, medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary clear, wavy. |
| C | 28+ | Dark-brown (10YR 4/3 moist), yellowish-brown (10YR 5/4 dry) gravelly loam; massive; soft, loose, slightly sticky, slightly plastic; pH 6.5; few roots; mixed rhyolitic-andesitic colluvium and aeolian sands. |

This soil is relatively stone free to 24-inch depth. Below this point, stones occupy 40 percent of the profile volume. Pumice is distributed throughout the profile.

SERIES V: Strongly developed Brown loam from river- and lake-laid sediments and occurring on undulating uplands.

Related association: *Juniperus/Artemisia/Agropyron*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-2 | Very dark-gray-brown (10YR 3/2 moist), light-gray-brown (10YR 6/2 dry) loam; weak, medium, platy breaking to single grain; loose, very friable, nonsticky, nonplastic; pH 6.5; roots few; boundary abrupt, smooth. |
| A12 | 2-6 | Dark-brown (10YR 3/3 moist), gray-brown (10YR .5/2 dry) silt loam; weak, fine, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 7.0; abundant roots; boundary abrupt, smooth. |
| A3 | 6-9 | Dark-brown (10YR 3/3 moist), brown (10YR 5/3 dry) silty clay loam; moderate, medium, subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 7.0; common roots; boundary abrupt, wavy. |
| B21 | 9-15 | Dark-brown (10YR 3/3 moist), dark-gray-brown (10YR 4/2 dry) silty clay; moderate, medium prismatic breaking to moderate, medium, angular blocky; hard, very firm, sticky, plastic; pH 7.5; roots few; boundary abrupt, wavy. |
| B22 | 15-23 | Dark-brown (10YR 4/3 moist), dark yellowish-brown (10YR 3/4 dry) clay; strong, medium prismatic breaking to strong, medium angular blocky; very hard, very firm, sticky, plastic; pH 8.0; few roots; boundary abrupt, wavy; few clayskins. |
| B3 | 23-26 | Yellowish-brown (10YR 5/4 moist), yellowish-brown (10YR 5/4 dry), silty clay loam; weak, medium, angular blocky; slightly hard, firm, slightly sticky, plastic; pH 8.0; few roots; boundary abrupt, smooth. |
| C(Dr) | 26+ | River- and/or lake-laid sediments with partially decomposed basalt stones. No roots. |

A strongly developed soil relatively stone free, 5 percent by volume. The B horizon definitely restricts root penetration. Calcareous deposits on soil peds in the B horizon and on the few stones in the B and C horizons. A discontinuous caliche at approximately 28 inches. Pumice distributed throughout the profile. Occasional small pockets of nearly pure pumice in the B horizon. The surface horizon is strongly vesicular.

SERIES VI: Strongly developed Brown loam from loess, very fine sands and small basalt fragments and occurring on undulating uplands.

Related association: *Juniperus/Artemisia/Agropyron*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-2 | Dark-brown (7.5YR 3/2 moist), gray-brown (10YR 5/2 dry) loam; moderate, medium, platy; soft, friable, slightly sticky, nonplastic; pH 7.0; few roots; boundary abrupt, smooth. |
| A12 | 2-8 | Very dark-gray-brown (10YR 3/2 moist), brown (10YR 5/3 dry) silt loam; weak, medium, subangular blocky; slightly |

| | | |
|---|---|---|
| | | hard, friable, slightly sticky, slightly plastic; pH 7.5; abundant roots; boundary abrupt and wavy. |
| B22 | 8-10 | Dark-brown (10YR 3/3 moist), brown (10YR 5/3 dry) clay loam; moderate, medium prismatic breaking to weak, medium, angular blocky; very hard, friable, sticky, plastic; pH 7.5; common roots; boundary clear, wavy. |
| B3 | 10-13 | Dark-gray-brown (10YR 4/2 moist), pale-brown (10YR 6/3 dry) silty clay loam; weak, medium, angular blocky; hard, firm, slightly sticky, slightly plastic; pH 8.0; few roots, boundary gradual, wavy. |
| C(Dr) | 13+ | Loess, very fine river sands, and partially decomposed basalt fragments; pH 8.0; few roots to 24 inches, none below this. |

A relatively stone-free soil (5 percent by volume). Root penetration restricted but not stopped by the B horizon. Pumice scattered throughout the profile. The surface horizon is strongly vesicular. Calcareous deposits in the lower B and in the C horizons.

SERIES VII: Brown sandy clay loam from rhyolitic-andesitic colluvium over indurate tuffaceous material on northeasterly slopes.

Related association: *Juniperus/Agropyron*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-3 | Very dark-gray-brown (10YR 3/2 moist), gray-brown (10YR 5/2 dry) sandy clay loam; moderate, medium, platy; soft, very friable, very slightly sticky, very slightly plastic; pH 6.0; few roots; boundary abrupt, smooth. |
| A12 | 3-9 | Very dark-gray-brown (10YR 3/2 moist), dark-gray-brown (10YR 4/2 dry) loam; weak, fine, subangular blocky; soft, friable, very slightly sticky, very slightly plastic; pH 6.5; common and abundant roots; boundary abrupt, wavy. |
| B1 | 9-18 | Dark-brown (10YR 3/3 moist), dark-brown (10YR 4/3 dry) silty clay loam; moderate, medium, angular blocky; slightly hard, friable, slightly sticky, slightly plastic; pH 7.0; common and abundant roots; boundary clear, smooth. |
| B21 | 18-32 | Dark-brown (10YR 4/3 moist), dark-yellowish-brown (10YR 4/4 dry) silty clay loam; strong, medium, angular blocky; hard, friable, slightly sticky, slightly plastic; pH 7.5; roots common; boundary abrupt, smooth. |
| B22 | 32-40 | Dark-brown (10YR 4/3 moist), dark-yellowish-brown (10YR 4/4 dry) clay loam; moderate medium prismatic breaking to strong, medium, angular blocky; very hard, friable, sticky, plastic; pH 8.0; few roots; boundary clear, wavy; few clayskins. |
| C(Dr) | 40-44 | Mixed rhyolitic-andesitic colluvium. Thin clayey material coating the stones. Roots extend into the rock cracks. |
| D | 44+ | Indurate tuffaceous material nonfriable when moist. |

The solum contains approximately 35 percent large stones. Few peds and rocks in the lower

B horizon coated with a calcareous deposit. Pumice distributed through the profile. The surface horizon is strongly vesicular and has many small pebbles adhering to the bottom of the plates.

Shallow phase: Shallow (20 inches) occurring near the tops of northerly slopes and having a weakly expressed B1 horizon; horizon number, sequence, and characteristics except thickness are the same as the series type.

Related association: *Juniperus/Agropyron*

SERIES VIII: Brown loam from rhyolitic-andesitic colluvium on southeasterly slopes.

Related association: *Juniperus /Agropyron-Purshia* variant

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-3 | Very dark-gray-brown (10YR 3/2 moist), gray-brown (10YR 5/2 dry) loam; moderate, coarse, platy; soft, very friable, very slightly sticky, very slightly plastic; pH 6.0; few roots; boundary clear, smooth. |
| A12 | 3-7 | Dark-brown (10YR 3/3 moist), brown (10YR 5/3 dry) loam; weak, fine, subangular blocky; soft, very friable, slightly sticky, slightly plastic; pH 6.5; roots abundant; boundary clear, smooth. |
| A3 | 7-12 | Dark-brown (10YR 3/3 moist), dark-brown (10YR 4/3 dry) silt loam; moderate, fine, subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; pH 7.0; roots abundant; boundary abrupt, wavy. |
| B1 | 12-15 | Dark-brown (10YR 3/3 moist), dark-brown (10YR 4/3 dry) silty clay loam; moderate, fine, angular blocky; slightly hard, very friable, slightly sticky, slightly plastic; pH 7.5; roots common; boundary abrupt, wavy. |
| B22 | 15-20 | Dark-gray-brown (10YR 4/2 moist), dark-yellowish-brown (10YR 4/4 dry) clay; strong, medium to fine, angular blocky; very hard, firm, sticky, plastic; pH 8.0; few roots; boundary abrupt, wavy. |
| C(Dr) | 20+ | Mixed rhyolitic-andesitic colluvium with thin, sandy clay material coating the stones; pH 8.0; roots penetrate the cracks between the stones. |

The solum contains approximately 40 percent large stones. Few calcareous deposits on soil peds and stones in the lower B horizon. Siliceous deposits on rocks in the C and lower B horizons. Pumice distributed throughout the profile. The surface horizon is strongly vesicular and has many small pebbles adhering to the bottom of the plates.

SERIES IX: Brown loam from rhyolitic-andesitic colluvium on south to southwesterly slopes.

Related association: *Juniperus/Artemisia/Agropyron-Astragalus*

| HORIZON | DEPTH (inches) | DESCRIPTION |
|---|---|---|
| A11 | 0-4 | Very dark-gray-brown (10YR 3/2 moist), gray-brown (10YR 5/2 dry) loam; weak, medium platy; soft, very friable, slightly sticky, slightly plastic; pH 6.0; common roots; boundary abrupt, smooth. |
| A12 | 4-7 | Dark-brown (10YR 3/3 moist), dark-gray-brown (10YR 4/2 dry) silt loam; weak, medium, subangular blocky; soft, friable, slightly sticky, slightly plastic; pH 6.5; common to abundant roots; boundary clear, wavy. |
| B21 | 7-16 | Dark-yellowish-brown (10YR 3/4 moist), dark-brown (10YR 4/3 dry) silty clay loam; moderate, medium, angular blocky; very hard, friable, sticky, plastic; pH 7.5; common roots, boundary clear, wavy. |
| B22 | 16-21 | Dark-brown (10YR 3/3 moist), dark-brown (10YR 4/3 dry) clay; strong, medium, angular blocky; very hard, friable, sticky, very plastic; pH 8.0; few roots; boundary clear, irregular; common clayskins. |
| C(Dr) | 21+ | Large, closely packed rhyolitic-andesitic colluvium with clay loam or silty clay on the stone surfaces. |

Stones occupy approximately 50 percent of the profile volume to the C(Dr) horizon. Stones occupy approximately 90 percent of this horizon. Some stones and soil peds in the C(Dr) and lower B horizons have calcareous deposits on their surfaces. Siliceous deposits are common on stones in the C(Dr) horizon. A discontinuous caliche often occurs at approximately 25 inches below the surface. The surface horizon is strongly vesicular. Pumice distributed throughout the profile.



GPO 987-609

Driscoll, Richard S.

1964. Vegetation-soil units in the central Oregon juniper zone. U. S. Forest Serv. Res. Paper PNW-19, 60 pp., illus.

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